RAILWAY MAINTENANCE
ENGINEERING

WITH NOTES ON

CONSTRUCTION

BY

WILLIAM H. SELLEW, A.S.M.E.

Author, "Steel Rails, their History, Properties, Strength and Manufacture"
Non-resident Lecturer on Railway Engineering, University of Michigan
Member American Railway Bridge and Building Association
Member American Railway Engineering Association

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PREFACE

THE book has been prepared from notes used by the author in his classes in Railway Engineering at the University of Michigan. While it has been written to present the subject from the view point of the student, an endeavor has been made to introduce matter of a sufficiently advanced character to make the book of value outside the classroom.

The question of major bridges has not been dealt with, as it was felt that this would be beyond the scope of the work and that it was a subject requiring special treatment. The same is true of yards and terminals, which are so fully covered by Mr. Droege's recent book that a general discussion here would be of little value to the student. Signaling has been touched upon, but the chapter on this subject is not exhaustive and is intended only to give a general knowledge of the work in this field. Very little cost data has been given, as apparently the studies now nearing completion in connection with the Federal valuation of the roads will constitute the best information to be obtained on this subject. The arrangement of chapters in the book follows the classification of investment accounts of the Interstate Commerce Commission, and no difficulty will be experienced in applying these unit costs to the present work.

As indicated in the title, the work is confined principally to maintenance. Railway development in this country has reached a stage where it is intensive rather than extensive, and the young engineer is probably more concerned with the study of the improvement of existing lines than the laying out of new roads. It should be observed that this field offers problems fully as important

as those connected with the construction of the railway. The development of the permanent way on American railways in the past has been mainly along empirical lines. At the present time, however, owing to the heavy wheel loads employed, the track is much more severely taxed than was formerly the case, and the need for more scientific methods is being felt. This may be said, in a measure, of other departments, and the trend of modern thought is distinctly in the direction of a more careful analysis of the results obtained in this service than was formerly generally supposed necessary.

The author has much pleasure in expressing his appreciation of the assistance given to him. He has endeavored to acknowledge this in each case throughout the book, and if he has been remiss in this respect it has been unintentional. He is much indebted to Professor A. R. Bailey for an examination of the manuscript and proofs. The proceedings of the American Railway Engineering Association and of the American Railway Bridge and Building Association have been freely quoted from and considerable material, in the preparation of the article on this subject, has been taken from the book "Electric Interlocking," written by the engineers on the staff of the General Railway Signal Company.

WILLIAM H. SELLEW.

MICHIGAN CENTRAL STATION,
DETROIT, MICHIGAN,
May, 1915

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Fig. 2 shows a reconnaissance map of a heavy grade on the Asheville and Spartanburg Division of the Southern Railway. This grade is about 5 per cent, and necessitates the use of safety switches in going down hill, and even with a pusher engine only part of the freight trains can be taken up the grade.

An examination of the country suggested a revision introducing sufficient distance to reduce the grade to 2 per cent. The increase of distance would be compensated for by the greater hauling capacity of the trains and would under certain conditions result in ultimate economy.

Owing to the cost of the contemplated change and the unbalanced traffic on the line, where the greater tonnage moves down the

hill, such a revision did not appear to be a profitable investment. If, however, conditions should change requiring heavier trains to be hauled over the hill, a reduction of the grade might well be considered.

At the time the examination was made the condition of the line was as follows:

Engine Rating.—The engine rating for southbound trains was determined by dynamometer test to be from 880 to 900 tons. This for 600 class consolidation engine with 180,000 lbs. on drivers.

Northbound engine rating, 800 tons, with the exception of the line from Tryon to Saluda. Engine rating for Saluda Hill, northbound, 275 tons. This for 600 class engines.

Engine Stage.—Between Spartanburg and Asheville.

Number of Trains.—Five or six freight trains and two passenger trains each way per day.

Tonnage.—Eighty-seven per cent from Asheville to Spartanburg and 13 per cent from Spartanburg to Asheville.

Operation.—There being only a limited number of trains on the line, the pusher makes extra trips alone from the top of the mountain to the foot and takes up empties, keeping a supply on top of the mountain. A northbound freight train with empties cuts off any that itself and the pusher cannot handle, at the foot of the hill, continues on to the top, fills out its regular load and proceeds to Asheville.

In regions not mapped by the Government, but where county atlases are to be obtained, a reconnaissance in force may be made over the country. By using the county maps as a basis and considering the roads as the base lines of the survey, it is possible to secure a very fair topographical map in a comparatively short time.

The roads usually are along the ridges and through the valleys; by running stadia lines over these and checking up the levels on any known elevations such as the elevation of the track, the levels can be adjusted and the distance can be checked as the work progresses by comparing the readings with the county maps, copies of which should be taken into the field. The contours are obtained by sketching in the general contour of the country between

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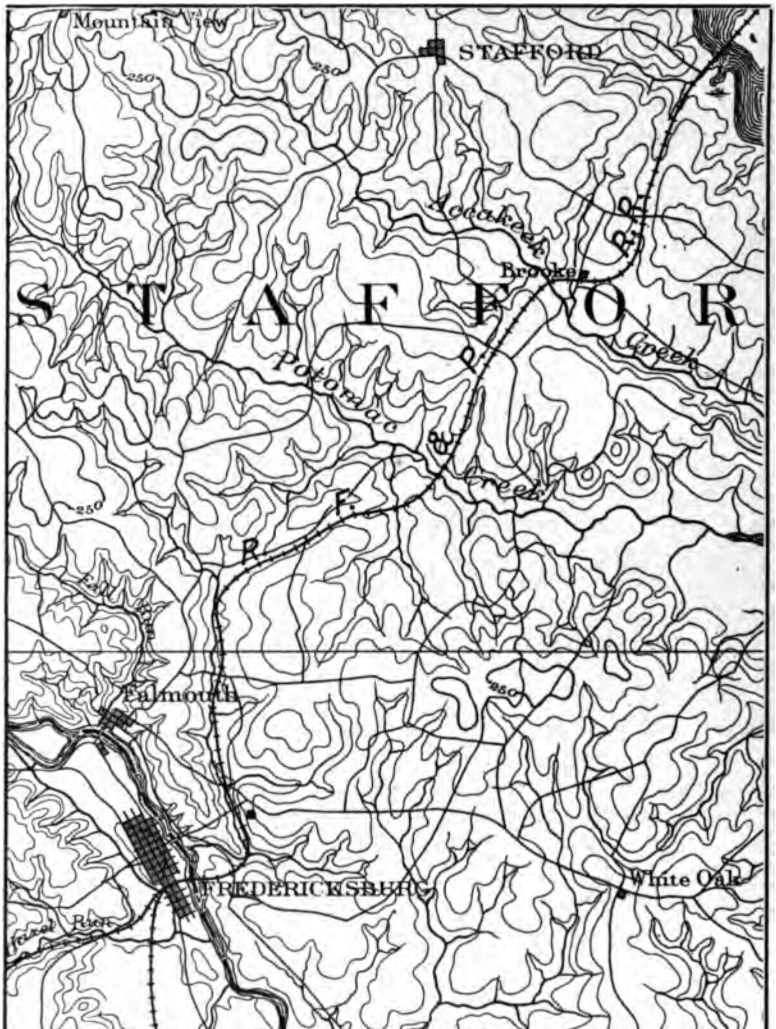

FIG. 1.—U. S. Geological Survey Map, Virginia-Maryland, part of Fredericksburg Sheet.

Scale $\frac{1}{125,000}$ Contour interval, 50 feet.

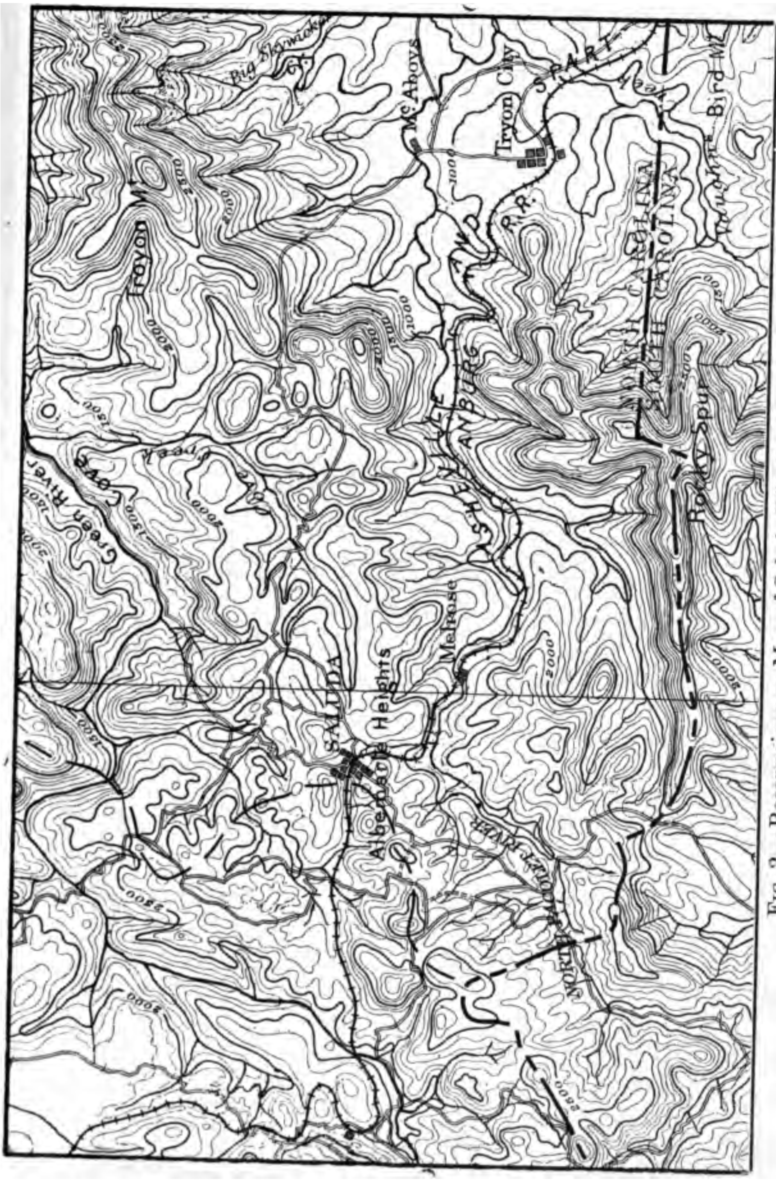

FIG. 2.—Reconnaissance Map of Saluda Hill, Southern Railway.

Scale $\frac{1}{125{,}000}$ Contour interval, 100 feet.

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the roads as the stadia party moves along and taking stadia shots to as many points as desired. After these readings have been subsequently reduced in the office, the proper contour lines may be drqwn upon the final map.

The use of the camera for obtaining topography was first employed in Switzerland, Italy and France. It was extensively used in the Government surveys in the western part of Canada. It has been employed in India and, in fact, all over the world at those places where large areas of rough country have to be mapped. It is essentially a method applicable to regions where a large amount of territory is to be covered rapidly in the field and is well adapted on this account for work in northern climates and high altitudes, where only a short period of the year can be utilized for field observations.

In making a camera survey a primary triangulation is first run and the camera stations located and their elevations determined.

The camera in its simplest form consists of an ordinary view camera provided with means for leveling and the addition of vertical and horizontal cross-hairs which are placed right in front of the plate. A horizontal plate with a circle is frequently provided upon which the angle can be read as with a transit and the views oriented from these readings in the subsequent plotting in the office. In very rough country, as in the Canadian surveys, a small telescope may be mounted on the camera for reading the vertical angle, but in ordinary railroad work the camera is generally leveled and if the country is very broken a sufficient number of camera stations are located to enable the necessary detail to be obtained.

Fig. 3 shows a photograph of the Canadian survey used in map construction.* The number of views taken at each station depends upon the angle of the lens. This angle varies in different cameras, but the range is not more than from 30 to 45 degrees. In taking the views they should overlap each other, and if the angle of the lenses is 45 degrees, the views should be taken about every 30 degrees.

* Topographic Surveying, H. M. Wilson, 1901, John Wiley & Sons, New York, p. 293.

FIG. 3.—Photograph of Canadian Survey and Used in Map Construction. (Wilson.)

Fig. 4 illustrates the method of plotting the results of the survey. The triangulation AB is first laid out to the scale of the map. Circles are then drawn with the camera stations A and B as centers and with a radius equal to the principal focal length of the camera. The focal length can be determined to within $\frac{1}{100}$ in. and the circles are drawn with this length taken actual size as the radius.

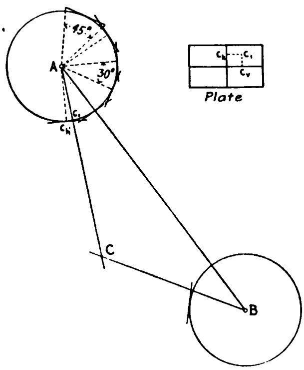

FIG. 4.—Projection of Camera Plates from a Station.

To determine the horizontal location of any point as C the distance c_1c_h is laid off on the trace of the plate from the center and the radial line Ac_1 is drawn, another radial line is drawn in a similar manner from station B, and the intersection of these lines determines the location of the point on the map.

The vertical distance above or below the camera is calculated by

similar triangles as illustrated in Fig. 5. For example the distance AC can be scaled from the map. Ac_0 is the focal length and c_1c_0 may be taken by a pair of dividers from the photograph. Then by similar triangles

$$\frac{C_1C}{c_1c_0}=\frac{AC}{Ac_0} \quad \text{or} \quad C_1C=c_1c_0\times\frac{AC}{Ac_0}.$$

The camera survey costs only about one-third as much as a plane table survey, and where no maps are available appears to afford the best means for making reconnaissance maps of considerable areas. Contour intervals of 10 ft. can be readily drawn by taking a sufficient number of views in ordinary country, and even if the region is wooded, contour intervals of 20 ft. may be determinded in most cases. However, if the contours are taken too closely the cost of the survey increases, due to the large amount of office work required.

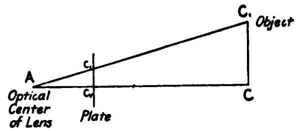

FIG. 5.—Projection of Camera Plates, Elevations.

2. Location.—In laying out the route of a railway two important factors govern the selection of the line. First, from commercial considerations the road must pass either through or near enough to a sufficient number of towns in the country between the terminal points to give rise to intermediate traffic, and second, from engineering considerations the line, except in a very flat country, must conform to the physical characteristics of the territory traversed.

While for these reasons the engineer can rarely locate the railway in a straight line between two termini and even less frequently with a uniform grade, nevertheless it will generally be found that in dealing with heavy traffic conditions the most direct method is the best. In applying this principle good judgment must, of course, be used, but the whole trend of modern railway construction is more and more toward bolder projects which naturally lend themselves to such treatment.

As an illustration of this may be cited the 40-mile cut-off

which the Delaware, Lackawanna & Western is now building from Clark's Summit, Pa., to Hallstead. This new line is being built to reduce the ruling grade eastbound from 1.23 per cent uncompensated to 0.68 per cent compensated, and westbound from 0.52 per cent uncompensated to 0.24 per cent compensated, and which will eliminate 327 ft. of rise and fall, 2440 degrees of central angle and 3.6 miles of line, involves the moving of 13,318,000 cu. yd. of material or 336,000 cu. yd. per mile, 60 per cent of which is rock. It is being constructed for three tracks and is estimated to cost $12,000,000, or practically $300,000 per mile.

Next to this Lackawanna work probably the heaviest railroad construction now under way is that involved in the building of the Magnolia cut-off of the Baltimore & Ohio, about 20 miles east of Cumberland, Md. This cut-off, 12 miles long, which is being built for double track with a maximum grade of 0.1 per cent, will be used for eastbound freight traffic, while all passenger trains and westbound freight trains will use the two existing tracks. Its construction involves the moving of over 3,500,000 cu. yd. of material, over 90 per cent of which is rock. It is estimated to cost $6,000,000, or $500,000 per mile. The cut-off eliminates 5.95 miles of distance and 877 degrees of curvature in addition to reducing the maximum grade eastbound from 0.5 per cent to 0.1 per cent and eliminating a helper grade 2.8 miles long.*

Three general conditions will govern the location of the line:

a. Where it is necessary to support the grade line.

b. Where the elevation to be overcome is not great and the traffic is sufficiently heavy to warrant the expense of heavy work to obtain a low grade line.

c. On heavy traffic lines located in prairie country, where the long, undulating slopes are on a steeper grade than that desired.

In the first case the line is generally made to follow a stream, and supporting ground is found on the sides of the valley. The development contemplated in Fig. 2 is an example of support-

* Description of the D. L. & W. and the Magnolia cut-offs taken from E. T. Howson's Lecture before the Detroit Engineering Society, January 8, 1915.

ing a grade line, where distance is introduced to reduce the grade.

This method of construction, except where considerable elevations are to be overcome, applies more usually to light traffic lines.

The conditions shown by the line in Fig. 6 are interesting to study in connection with the second case.

The territory traversed is quite broken. The line runs at right angles to the direction of the important streams and consequently consists of a series of undulations as it passes over the different drainage areas. None of these undulations, however, are of great magnitude, as the difference in elevation between the streams in the valleys and the summits between their respective watersheds is comparatively small. One per cent grades and curves as high as 5 degrees are used.

In looking over the situation there are obviously two courses to follow: First, to utilize as much as possible of the existing line and make revisions of the line at those places where the worst curvature and grades occur; and second, to lay a new line without reference to the present location except in so far as the principal towns are concerned.

The latter course would appear to be worth investigating, as from the profile it is apparent that the road reaches nearly the same elevation after rising from the River Valley at *A* as that attained at Pelton. The grade line is constantly rising and falling between these points, but the elevation at no place varies in the entire distance more than from 1243 ft. above sea level, at the highest point, to in the neighborhood of 850 ft. above mean tidewater at the lowest. This difference in elevation should not appear at all serious, and the magnitude of the work involved would not be out of the way as compared with what has been done on the Pennsylvania between Pittsburgh and Philadelphia, the Lackawanna, the Baltimore & Ohio along the Cumberland River, and other heavy traffic lines.

A great deal of the country in the Middle Western States consists of prairies which, while they appear to the eye to be level or nearly so, when the line is run are found to consist of long slopes

having gradients which may reach 1 per cent. If it is desired to reduce the grade of the line to less than the natural grade of the country, the only practical method is to raise the elevation at the foot of the slope by making heavy fills and by cutting into the summit. As long cuts are objectionable on account of the difficulty of obtaining proper drainage, the usual practice is to raise the line on embankments, involving heavy expense in what at first sight would appear to be an ideal country to locate the road.

At the present stage of this country's development the railroad engineer is more frequently called upon to relocate or revise an existing line than to construct an entirely new railway. He is thus evidently in a position to obtain accurate information in reference to the physical condition of the country traversed, such as the flow of streams, character of the sub-strata, etc., as well as the traffic which the new line must be built to carry economically. This is a decided advantage, and one which enables the engineer to proceed with much more certainty than in the case of a new line in undeveloped country.

Fig. 7 shows a plan for a revision of line where the heavy passenger traffic warrants a considerable expenditure to eliminate curvature. The treatment in this case is somewhat different from that used in Fig. 6, as the route had been selected from a reconnaissance study map and the line actually run in on the ground. Fig. 8 is a photograph of the present line.

3. Construction.—In constructing the road it is usually divided into sections about ten miles in length in charge of a resident engineer. The resident engineer is responsible for the work on his residency except in the case of major structures, where decisions as to the depth of foundations and other special problems are made by the chief engineer or his assistant.

The resident engineer on taking charge of his residency should at once establish permanent bench marks and reference points for the located alignment. The line should next be cross-sectioned and slope stakes set for the grading. From the cross-section notes the construction profile should then be prepared, showing in pencil the approximate quantities and overhaul. From this pro-

file the method of carrying on the work may be outlined and the disposition of the material from cuts decided upon. The profile should also show the classification of the material to be moved, as earth, loose rock, solid rock, and indicate clearly the borrowed quantities where the excavation is not sufficient for the embankment.

Fig. 9 shows the form of construction profile used in the building of the Choctaw, Oklahoma & Gulf Railroad Company's

FIG. 8.—View of Line Shown in Fig. 7.

line across the State of Arkansas in 1899.* In plotting the haul curve shown in the lower part of the profile each horizontal space is taken as 100 cubic yards. Starting at the point of division of haul in the cut Sta. 3965+87, and adding the yards at each station to the total yardage from the preceding stations the curve

* Manual for Resident Engineers, F. A. Molitor and E. J. Beard, 1912, John Wiley & Sons, New York, pp. 28, 57.

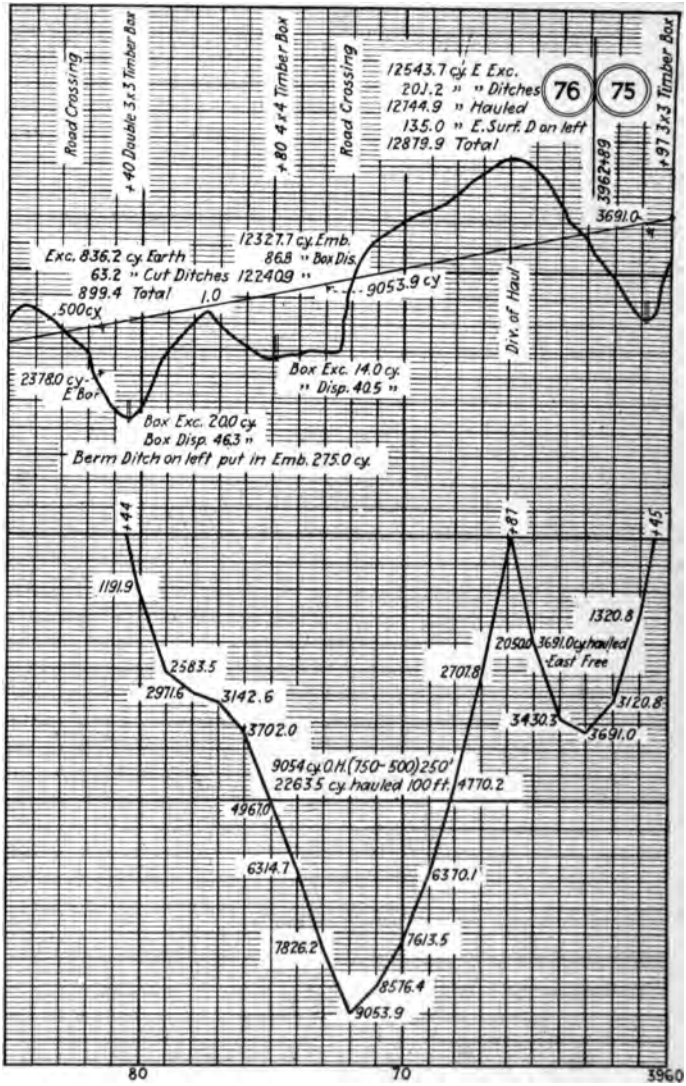

FIG. 9.—Construction Profile. (Molitor and Beard.)

is downward to the end of the cut. From this point the curve rises at each station an amount equal to the embankment yardage at that station until it reaches the horizontal line at Sta. 3980+44, when the material from the cut is exhausted, and after this point is reached it is necessary to draw the excavated material from the next cut or borrow for the fill.

Drawing a horizontal line at the center of bulk of the fill it is seen that the material is hauled an average length of 750 ft., and as the limit of free haul was 500 ft., the overhaul amounted to $9054 \times (750-500)$ or 22,635 cu. yd. hauled 100 feet.

As the work progresses approximate monthly estimates of work done are furnished the contractor, from which ten per cent is usually deducted. Progress reports should be prepared by coloring on a copy of the profile the excavation moved and the embankment placed. An index to the color scheme should preferably be placed on the profile to show and compare the work done during different months.

Final estimates should be made whenever any piece of work is completed.

4. Estimation of Quantities.—In making preliminary estimates of grading if the ground is level or approximately so the quantities are taken from a table of level cuttings which gives the cubic yards in a 100-ft. station for different center heights taken from the profile. These tables are merely the cubic yards contained in a section of the roadway 100 ft. long and of constant area and are based on the assumption that the ground is level and of constant distance from the grade line throughout the 100-ft. section.

For paying the contractor it is necessary to compute the quantities more accurately. This is usually done by the method of averaging end areas. The end area may be determined by plotting the section, but is more generally calculated directly from the readings in the cross-section book. Sections to determine the end areas should be taken every 100 ft., and where the ground is irregular more frequently. In estimating the quantities at the end of a cut where the section at the grade point has no area, the yardage should be calculated by multiplying the end area of the last section by one-third of the length.

Fig. 10 shows the form in which the quantities are entered in the cross-section book as used on the construction of the Choctaw

The areas may be calculated from the notes by dividing the section up into figures at each reading and taking their combined area. For example, at Sta. 4009+25 the calculation would be

$$\text{Area left of center}\quad 13.4\left(\frac{4.9+3.6}{2}\right)-3.6\left(\frac{13.4-8}{2}\right)=47.32$$

$$\text{Area right of center}\quad 15.5\left(\frac{4.9+5.0}{2}\right)-5.0\left(\frac{15.5-8}{2}\right)=57.97$$

$$\overline{105.29}$$

the terms deducted being the areas of the triangles outside of the slopes. Where the slope of the ground is uniform, formulæ, diagrams or tables are frequently used to reduce the actual numerical work.

The area of the section is then averaged with the area of the section next preceding and the corresponding yardage taken from a table which gives the cubic yards for different end areas 100 ft. apart.

End area formula:

$$V=\frac{\frac{1}{2}(A+B)\times L}{27}.$$

The volume of any prismoid is given by the following formula:

Prismoidal formula:

$$V=\frac{\frac{1}{6}(A+4C+B)\times L}{27},$$

where A and B are the end areas, L the perpendicular distance between the ends of the prismoid and C the area of a section parallel and midway between the ends.

This latter formula, on account of the work involved, is rarely used in calculating earthwork, and if greater accuracy is desired

SECTION

STA.	ELEV	GRADE	CUT OR FILL LEFT	CUT OR FILL C	CUT OR FILL RIGHT
+93	335.30	335.26	+0.2 / 10.2	0.0	-0.7 / 9.0
4005	335.50	335.30	+0.5 / 10.5	+0.2	0.0 / 4.0 -0.2 / 8.3
+06	335.70	335.34	+0.8 / 10.8	+0.4	0.0 / 10.0
6	341.00	335.90	+5.1 / 15.1	+5.1	+5.0 / 15.0
+50	343.40	336.20	+6.7 / 16.7	+7.2	+7.5 / 17.5
7	344.90	336.50	+7.8 / 17.8	+8.0	+8.4 / 18.4
50	346.40	336.80	+9.6 / 19.6	+9.6	+9.6 / 19.6
8	346.20	337.10	+9.0 / 19.0	+9.1	+8.3 / 18.3
+50	343.60	337.40	+7.5 / 17.5	+6.1	+4.7 / 14.7
+75	339.60	337.65	+3.0 / 13.0	+2.3	+1.3 / 11.3
+85	337.60	337.61	0.0 / 10.0	0.0	0.0 / 10.0
9	334.20	337.70	-2.5 / 11.3	-3.5	-2.8 / 11.8
+25	332.90	337.85	-3.8 / 13.4	-4.9	-5.0 / 15.5
+50	330.70	338.00	-5.7 / 16.5	-7.3	-8.2 / 20.1
+75	330.40	338.15	-7.4 / 18.1	-7.8	-8.1 / 20.1
4009+75	Timber	Box	2'×2'		
4010	333.20	338.30	-5.2 / 15.8	-5.0	-4.8 / 14.8
+41	338.60	338.55	0.0 / 10.0	0.0	0.0 / 10.0

AREAS EXCAVATION.	AREAS Embankment.	Cubic Yards. EXCAV.	Cubic Yards. EMBANK.	Remarks.
			7758.4	Forward
1.00	2.80	0.2	2.8	
3.95	0.40	0.6	0.9	
8.16	0.0	13	0.1	
127.25		235.3	7761.3	Est. 7761.2 Cu. Yds. Emb. / " 1507.1 " " in E. Bor.
194.12		297.6		
235.80		398.1		
284.16		481.4		
263.85		507.4		
160.82		393.2		
40.44		97.3		
0.0	0.0	9.2	0.0	Est. 1112 C.Y. E. Backfill
	61.70	2422.0	17.1	Est. 2422.0 C.Y. Exc. / Est. 260.2 C.Y. Exc. S.B.
	105.20		77.3	Est. 1900.0 C.Y.E. / Est. 782.2 C.Y. S.R.
	189.92		136.6	Solid Rock Swelled 50%
	215.27		187.6	2484.3 c.y. hauled & free / 1979 " " " "
	117.48		154.0	—Box foundation— / Est. 25 C.Y. E. Exc. into Emb.
0.0	0.0	0.0	89.2	
			661.8 / 75.8	Box Displacement / Est. 646.0 C.Y. Emb.

FIG. 10.—Cross-section Notes. (Molitor and Beard.)

than that obtained by the method of averaging end areas, a prismoidal correction is applied.

The error in computing by averaging end areas increases as the square of the difference in center height and is not affected by the absolute volume of the solid. This error nearly always gives a quantity in excess of the true amount, but the excess is small and will probably not be more than 1 per cent for any usual section of road.*

In estimating the grading quantities in the Federal valuation of the railroads the cross-section notes are plotted directly in the field in a loose-leaf book, as shown in Fig. 11*A*.† Ballast soundings are taken at the center of the track to determine the top of the roadbed. It will be observed that the scale used gives a figure which it is more convenient to planimeter than that plotted to the ordinary scale of 10 ft. = 1 in., for both horizontal and vertical distances, while the same setting of the planimeter may be employed as with the latter scale.

In the use of the planimeter in connection with notes plotted in the field, three readings should be taken of each area and the maximum variation allowed should not exceed 1 per cent between extreme readings. Two men, one to run the planimeter and the other to compile the results, can compute the quantities for about 5 miles of road per day, which is probably more rapid progress than can be obtained by the ordinary methods of calculating the areas by formulæ.

In Fig. 11*B* is illustrated a section of roadbed in side-hill work. This may be plotted directly in the field as the cross-section party moves along and the slope stakes set by measuring the distance from the center line as shown by the drawing. For this character of work it is desirable to use a cross-section book about 15 ins. square.

5. Curves and Spirals.—The most difficult part of the track to maintain is that on curves.

To enable the train to ride properly on the curve the resultant

* See Economic Theory of the Location of Railways, A. M. Wellington, 1900, John Wiley & Sons, New York, p. 896.

† The size of the page has been somewhat increased over that shown.

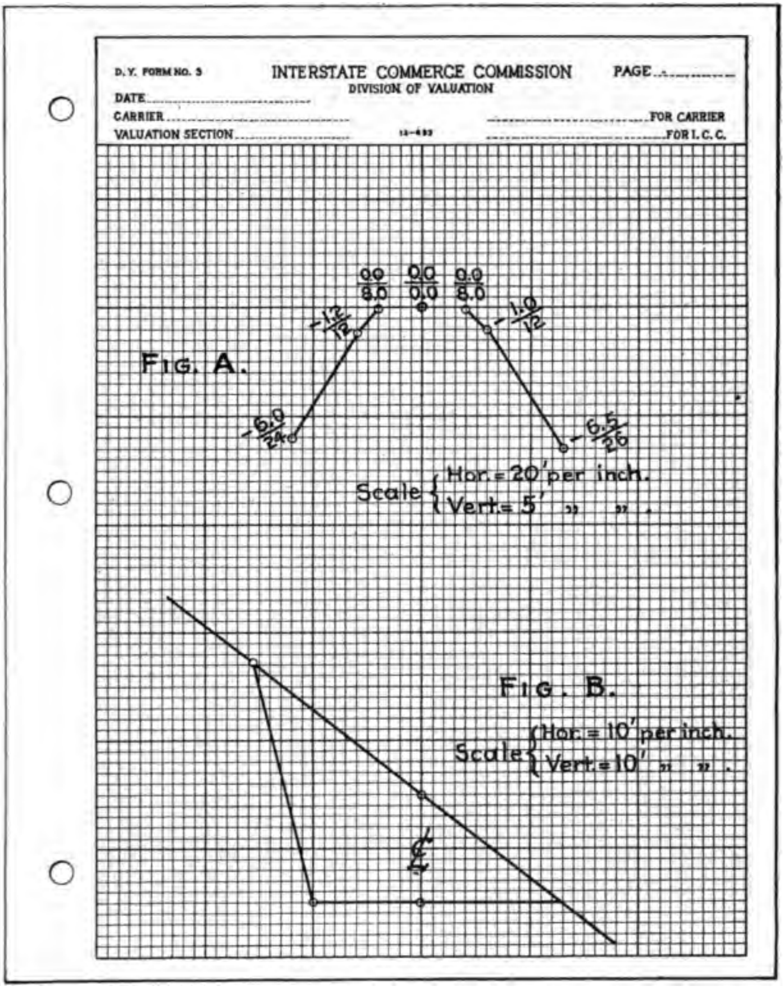

FIG. 11.—Cross-section Note Book Used in Federal Valuation.

of the weight of the train and the centrifugal force should act at right angles to the plane of the track, and as this resultant obviously cannot be vertical, the plane of the track which is perpendicular to it should not be horizontal.

The elevation of the outer rail on curves can be determined as follows:*

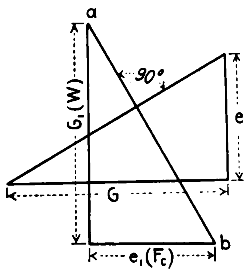

FIG. 12.—Elevation of Outer Rail on Curves.

Referring to Fig. 12,

e = Elevation of outer rail in feet;
v = Velocity of train in feet per second;
G = Gauge of track in feet;
R = Radius of curve in feet;
$G_1 = W$ = Weight of train in pounds;
$e_1 = F_c$ = Centrifugal force in pounds;
ab = Resultant of W and F_c.

Then from similar triangles we have

$$\frac{e}{e_1}=\frac{G}{G_1} \quad \text{but} \quad e_1=F_c=\frac{Mv^2}{R}=\frac{W}{g}\cdot\frac{v^2}{R},$$

$$e=\frac{e_1G}{G_1}=\frac{\frac{W}{g}\cdot\frac{v^2}{R}\cdot G}{G_1}=\frac{Wv^2G}{GWR}=\frac{v^2G}{gR}=\frac{Gv^2}{32.16R}.$$

Or if

V = Velocity in miles per hour;
D = Degree of curve;
E = Elevation of outer rail in inches at the gauge line,

then

$$E=.00066DV^1.\dagger$$

Table I gives the results calculated by this formula.

* Manual Am. Ry. Eng. Asso., 1911, p. 112.

† Approximate in that it is assumed that $R=\frac{5730}{D}$.

TABLE I

ELEVATION OF OUTER RAIL IN INCHES (AM. RY. ENG. ASSN.)

Degree of Curve.	Velocity in Miles per Hour.							Degree of Curve.
	10.	20.	30.	40.	50.	60.	70.	
1	0	$\frac{1}{4}$	$\frac{5}{8}$	$1\frac{1}{8}$	$1\frac{5}{8}$	$2\frac{3}{8}$	$3\frac{1}{4}$	1
2	$\frac{1}{8}$	$\frac{1}{2}$	$1\frac{1}{8}$	$2\frac{1}{8}$	$3\frac{1}{4}$	$4\frac{3}{4}$	$6\frac{1}{2}$	2
3	$\frac{1}{4}$	$\frac{3}{4}$	$1\frac{3}{4}$	$3\frac{1}{8}$	$4\frac{7}{8}$	$7\frac{1}{8}$	....	3
4	$\frac{1}{4}$	1	$2\frac{3}{8}$	$4\frac{1}{4}$	$6\frac{5}{8}$	....	....	4
5	$\frac{3}{8}$	$1\frac{1}{4}$	3	$5\frac{1}{4}$	$8\frac{1}{4}$	....	....	5
6	$\frac{3}{8}$	$1\frac{5}{8}$	$3\frac{1}{2}$	$6\frac{1}{4}$	....	....	....	6
7	$\frac{1}{2}$	$1\frac{7}{8}$	$4\frac{1}{8}$	$7\frac{3}{8}$	....	....	....	7
8	$\frac{1}{2}$	$2\frac{1}{8}$	$4\frac{3}{4}$	....	....	....	....	8
9	$\frac{5}{8}$	$2\frac{3}{8}$	$5\frac{3}{8}$	....	....	....	....	9
10	$\frac{3}{4}$	$2\frac{5}{8}$	$5\frac{7}{8}$	....	....	....	....	10

The maximum elevation should not exceed 6 or 7 ins., although in some cases more elevation than this is allowed. Too great elevation is undesirable, especially where the traffic is mixed, i.e., passenger and freight, or on single track where the speeds in opposite directions are generally different.

On side tracks very little elevation should be placed on the curves, and, in fact, in most cases of tracks for industrial plants it is well to omit the elevation altogether. The curves on these tracks may reach 30 or 40 degrees or more, but the train movement is so slow that no appreciable effect of centrifugal force is noticed.

In large cities, where the track room is cramped, industrial tracks are often built on very sharp curves, and special engines with short wheel bases and long coupled between engine and tank are employed to switch over these tracks. Where the use of sharp curves cannot be avoided, the territory should be divided into districts and a certain maximum curvature established for each district, based on the power available for switching in that particular district. For side tracks along the line where switching is done by road engines, the curves should be of a longer

radius than that used in the districts where switch engines are employed.

On sharp curves the gauge should be widened. On some roads it is the practice to allow a certain amount of extra width in the gauge for every degree of curve, but apparently this is unnecessary refinement, and the following rule answers all practical purposes:

On curves greater than 5 degrees and up to and including 14 degrees, widen the gauge one-half in.

On curves greater than 14 degrees, widen the gauge 1 in.

The gauge may be widened by the use of an iron shim inserted between the lug of the track gauge and the head of the rail. It is not customary to widen gauge in the curve of a turnout.

On account of the extra resistance in hauling a train around a curve, it is desirable to compensate or reduce the rate of grade on main line curves a sufficient amount to give a uniform pull at the draw bar of the locomotive when ascending a grade. The amount of compensation to allow is a mooted question among engineers, but .04 ft. per degree of central angle (.04 per cent per degree of curvature) may be taken as representing good practice.* In the case of long curves placed on limiting grades where it is necessary to haul long trains the author has found it desirable to make ample provision for the extra resistance due to the curve.

On all important lines the curves have some sort of easement or spiral approach to cause the resultant of the weight of the train and the centrifugal force at every point to be perpendicular to the plane of the track in passing from the tangent to the circular curve.

These spirals in general have the form of a cubic parabola in which the degree of curve varies directly as the length of the spiral, the deflection angle as the square of the length and the offset distance as the cube of the length.

As the elevation and the curvature increase directly with the distance in passing from the tangent to the circular curve,

* The American Railway Engineering Association recommends 0.035.

the result is that the inclination of the track is proportional to the centrifugal force at any point.

Almost any of the spirals in common use will give the same results as far as the riding of the track is concerned, and in adopting a spiral the subject should be approached with the view of deciding upon some method which will enable the curve used to be run in on the ground with the smallest amount of difficulty.

In staking out easement curves, the easement is generally given the length that conditions permit, without too much expense in widening cuts and fills. It is good practice to use an easement of 150 ft to the degree and in elevating the outer rail divide this easement into four parts per degree and elevate the rail for each sub-station; that is, first 37½ ft. sub-station, ½ in.; second, 1 in.; third, 1½ ins.; and the fourth, at 150 ft., 2 ins. These figures, of course, refer to high-speed track where it is necessary to elevate in the neighborhood of 2 ins. per degree. (See Table I.)

Where it is not convenient to use a length of spiral of 150 ft. to the degree this may be reduced to possibly a minimum of 100 ft. to the degree on the main line and 80 ft. to the degree on branch lines.

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CHAPTER II

LAND

6. Basic Divisions of Land.—The present system of surveying the public lands in the United States was inaugurated by a committee appointed by the Continental Congress and of which Thomas Jefferson was chairman.

On the 7th of May, 1784, this committee reported "An ordinance for ascertaining the mode of locating and disposing of lands in the western territory, and for other purposes therein mentioned." This ordinance required the public lands to be divided into "hundreds" of 10 geographical miles square, and those again to be subdivided into lots of 1 mile square each, to be numbered from 1 to 100, commencing in the northwestern corner, and continuing from west to east and from east to west consecutively. This ordinance was considered, debated, and amended, and reported to Congress April 26, 1785, and required the surveyors "to divide the said territory into townships of 7 miles square, by lines running due north and south, and others crossing these at right angles. . . . The plats of the townships, respectively, shall be marked by subdivisions into sections of 1 mile square, or 640 acres, in the same direction as the external lines and numbered from 1 to 49. . . . And these sections shall be subdivided into lots of 320 acres." This is the first record of the use of the word "township" and "section."

May 3, 1785, the section respecting the extent of townships was amended by striking out the words "seven miles square" and substituting the words "six miles square." The records of these early sessions of Congress are not very full or complete; but it does not seem to have occurred to the members until the 6th of May, 1785, that a township 6 miles square could not

contain 49 sections of 1 mile square. At that date a motion to amend was made, which provided, among other changes, that a township should contain 36 sections; and the amendment was lost. The ordinance as finally passed, however, on the 20th of May, 1785, provided for townships 6 miles square, containing 36 sections of 1 mile square.

The system of rectangular surveying, authorized by law May 20, 1785, was first employed in the survey of United States public lands in the State of Ohio.

The boundary line between the States of Pennsylvania and Ohio, known as "Ellicott's line," in longitude 80° 32′ 20″ west from Greenwich, is the meridian to which the first surveys are referred. The townships east of the Scioto River, in the State of Ohio, are numbered from south to north, commencing with No. 1 on the Ohio River, while the ranges are numbered from east to west, beginning with No. 1 on the east boundary of the State, except in the tract designated "U. S. military land," in which the townships and ranges are numbered, respectively, from the south and east boundaries of this tract.

During the period of 130 years since the organization of the system of rectangular surveying, numbered and locally-named principal meridians and base lines have been established, as shown by Table II.

The tiers of townships are numbered, to the north or south, commencing with No. 1, at the base line; and the ranges of the townships, to the east or west, beginning with No. 1, at the principal meridian of the system.

In the first surveys, which covered what is now part of the State of Ohio, the sections were numbered from 1 to 36, commencing with No. 1, in the southeast corner of the township, and running from south to north in each tier to No. 36 in the northwest corner of the township. But under an Act of Congress, approved May 18, 1786, the thirty-six sections into which a township is subdivided are numbered, commencing with No. 1 at the northeast angle of the township, and proceeding west to No. 6, and thence proceeding east to No. 12, and so on, alternately, to No. 36 in the southeast angle.

TABLE II

MERIDIAN AND BASE LINES OF UNITED STATES SURVEYS

Principal Meridians.	Governing Survey (wholly or in part) in States of—	Longitude W. from Greenwich. ° ′ ″	Runs near—	Base Line.	Latitude N. ° ′ ″	Runs near or with—
First	Ohio	84 48 50	State line	....	....	Findlay, Ohio.
Second	Indiana and Illinois	86 28 00	Lebanon and Indianapolis	....	38 28 20	Salem, Ind.
Third	Illinois	89 10 15	Cairo	....	38 28 20	Centralia.
Fourth	Wisconsin and Minnesota	90 28 45	Plattsville, Wis	....	42 30 00	State line, Wis.
Fourth	Illinois	90 28 45	Rock Island, Ill	....	40 00 30	Beardstown, Ill.
Fifth	Arkansas, Missouri, Iowa, S. Dakota, N. Dakota, and Minnesota	91 03 42	Powhatan, Ark., and Dubuque, Ia.	....	34 44 00	Little Rock.
Sixth	Kansas, Nebraska, Wyo., Colorado, and S. Dakota	97 23 00	Wichita, Kans., and Columbus, Neb.	....	40 00 00	On State line.
Michigan	Michigan	84 22 24	Lansing	Michigan	42 26 30	Detroit.
Tallahassee	Florida	84 16 42	Tallahassee	Tallahassee	30 28 00	Tallahassee.
St. Stephens	Alabama and Mississippi	88 02 00	Mobile	St. Stephens	31 00 00	State line.
Huntsville	Alabama	86 34 45	Huntsville	Huntsville	35 00 00	North State line.
Choctaw	Mississippi	90 14 45	Jackson, Miss	Choctaw	31 54 40	Hazelhurst.
Chickasaw	Mississippi	89 15 00	Holly Springs	Chickasaw	34 59 00	Old Tennessee boundary.
Washington	Mississippi	91 09 15	Natchez	St. Stephens	31 00 00	State line.
St. Helena	Louisiana	91 09 15	Baton Rouge	St. Stephens	31 00 00	State line.
Louisiana	Louisiana	92 24 15	Alexandria	St. Stephens	31 00 00	State line.
New Mexico	New Mex. and Colorado	106 53 40	Socorro	New Mexico	34 15 25	Socorro.
Navajo	New Mex. and Arizona	108 32 45	....	Navajo	35 45 00	
Salt Lake	Utah	111 54 00	Salt Lake City	Salt Lake	40 46 04	Salt Lake City.
Uintah	Utah	109 57 30	....	Uintah	40 26 20	
Boise	Idaho	116 24 15	Boise City	Boise	43 22 31	Idaho Falls.
Mount Diablo	California and Nevada	121 54 48	San Jose	Mount Diablo	37 52 49	San Francisco.
Humboldt	California	124 08 00	Eureka	Humboldt	40 25 12	Cape Mendocino.
San Bernardino	California	116 56 15	San Diego	San Bernardino	34 7 10	San Bernardino.
Willamette	Oregon and Washington	122 44 20	Portland, Ore	Willamette	45 31 00	Portland, Ore.
Black Hills	South Dakota	104 03 00	Wyoming boundary	Black Hills	44 00 00	Rapid City.
Montana	Montana	111 38 50	Helena	Montana	45 46 48	Billings.
Gila and Salt R.	Arizona	112 17 25	Phoenix	Gila and Salt R	33 22 40	Phoenix.
Indian	Oklahoma and Indian Ter.	97 14 30	Guthrie	Indian	34 30 00	Duncan.
Cimarron	Oklahoma Territory	103 00 00	N. Mex. boundary	Cimarron	36 30 00	Texas boundary.
Wind River	Wyoming	108 48 40	....	....	43 1 20	
Ute	Colorado	108 33 25	....	....	39 6 40	

This method of numbering sections is still in use.

All of the territory north of the Ohio River and west of the Mississippi River not owned by individuals previous to the dates of cession to the United States government as well as portions of the States of Florida, Alabama, Mississippi and Tennessee have been laid out by the government in this manner.

This has savc large sums of money to property owners by preventing the confusion and litigation which is common in the old Colonial States.

Writing Descriptions of Property to be Acquired.—Descriptions should be written with due regard to accuracy, brevity, simplicity and clearness; avoiding double description and legal verbiage.

The plats to accompany the description should show the cardinal points and the courses and distances given in the description.

The most logical starting-point should be chosen and carefully described; the best defined of the two courses should then follow, regardless of the direction of rotation, although rotation in the same direction as the hands of a clock is preferable.

The area should be given in description and shown on plat.

The following grammatical errors should be guarded against: "33 feet on *either* side," when 33 feet on *each* side is meant; "parallel *to*," when parallel *with* is meant; intersection of Brown's line *and* Smith's line, when *with* Smith's line is meant.

In describing the boundaries of land it is desirable to calculate the latitude and departures of the corners of the area and make a closure on the starting-point which will thus insure the accuracy of the lengths and courses given and avoid possible future lawsuits due to any inaccuracy in the description.

The following typical cases and descriptions are given for general guidance and should not be blindly followed:

7. United States Surveys.—*First: On Surveyed Lines.*—Fig. 13. All that certain strip or parcel of land situate in Section One (1); Township One (1) North; Range One (1) West of the Second Principal Meridian, in the County of.................. State of...................., Described as follows, to wit:

A strip of land one hundred (100) feet in width, fifty (50) feet on each side of the following described center line: Commencing at a point in the East line of said Section, 1760 feet North of the Southeast Corner thereof, Thence Northwestwardly in a straight line 6230 feet, more or less, to a point in the West Line of said Section 1760 feet North of the Southwest corner of the Northwest Quarter thereof; and containing an area of 14.302 acres more or less.

NOTE.—The above is designed to be used where even widths of right of way are acquired upon lines located, either under

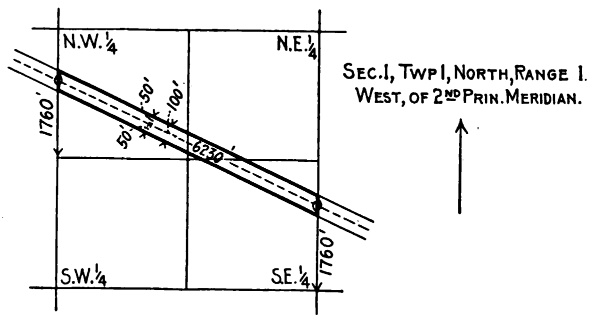

FIG. 13.—United States Surveys, on Surveyed Lines.

construction or in prospect and where it is necessary to absolutely fix the position of the strip of land to be conveyed, by reference to the lines or corners of the United States Surveys.

Second. Tracts of Land.—Fig. 14. All that certain strip or parcel of land situate in.......... County, State of............ Described as follows, to wit:

The South one hundred and seventy-five (175) feet of the Northeast Quarter of the Northeast Quarter of Section One (1), Township One (1) North; Range One (1) West of the Second Principal Meridian, County and State aforesaid, containing an area of............ Acres, more or less.

NOTE.—The above is to be used for tracts of land in United States Surveys.

Third. Strips along Existing Tracks.—Fig. 15. All strip or parcel of land situate in.......................Cou State of..........................., Described as follows wit:

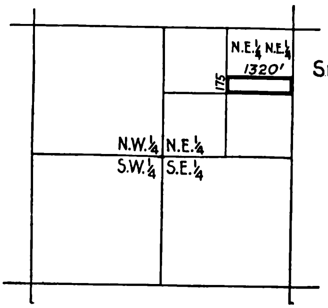

FIG. 14.—United States Surveys, Tracts of Land.

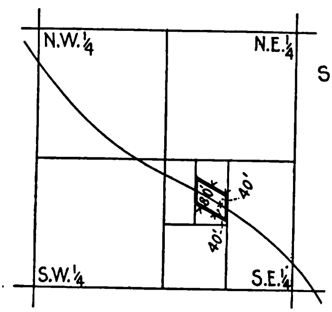

FIG. 15.—United States Surveys, Strips along Existing Tracks.

A strip of land eighty (80) feet in width, forty (40) fee each side of the center line of the Main Track of the......... Rail.............., as the same is now located and constru over and across the East Half of the Northwest Quarter of Southeast Quarter of Section One (1); Township One (1) No Range One (1) West of the Second Principal Meridian, Cou

and State aforesaid; having a length of..............feet, and containing an area of............Acres, more or less.

NOTE.—The above is designed to be used where rights of way are acquired with reference to existing main tracks.

8. Irregular Surveyed Land.—Fig. 16. All that certain strip of land situate in....................Township,.............. County, State of............., Described as follows, to wit:

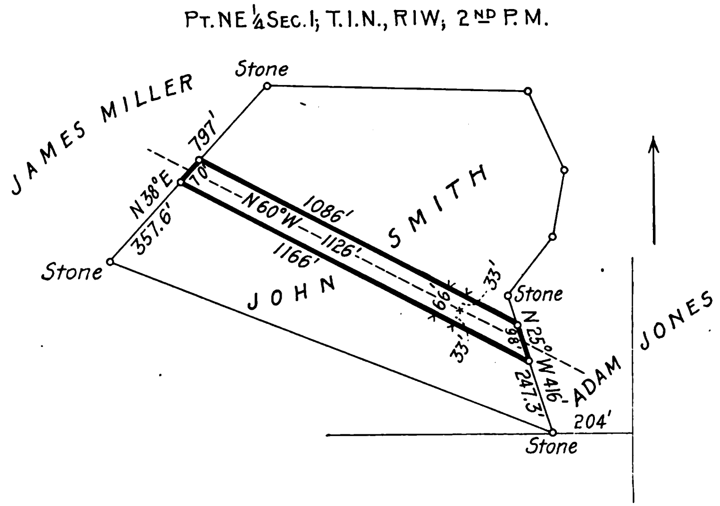

FIG. 16.—Irregular Surveyed Land.

Beginning at a point in the line dividing lands of the Grantor from lands of Adam Jones on the east and distant N. 25° W. 247.3 feet from a stone at the Southeasterly corner of Grantor's lands: Thence N. 60° W. 1166 feet parallel with and 33 feet distant Southwestwardly from the center line of the original main track of the................Rail..............Company to a point in the line dividing said lands of the Grantor from lands of James Miller on the West, and distant N. 38° E. 357.6 feet from a stone at the Southwesterly corner of the Grantor's said lands: Thence along said dividing line N. 38° E. 70 feet, more or less, to a point

distant 33 feet Northeastwardly measured at right angles i the center line aforesaid: Thence S. 60° E. 1086 feet pa with and 33 feet distant Northeastwardly from said center to a point in the line dividing the lands of Grantor from l of Adam Jones, heretofore mentioned; Thence along said divi line S. 25° E. 98 feet, more or less, to the place of begin and containing an area of 1.706 acres, more or less, and bei part of a certain tract of land conveyed by William Brown wife to said John Smith, the Grantor herein, by their D Dated,..............A.D........... and recorded in..... Volume.........., page.........., of the Deed Records of County and State aforesaid.

NOTE.—The above is designed to be used in all cases w the lands to be conveyed should be referred absolutely by des tive field notes to the actual lines of irregular shaped tract land, which have no definite location other than mere ide on the ground. It is usually the best practice in such case mention the Grantors' next preceding recorded title. This met can be used for additional and irregular shaped parcels of to be acquired.

9. Additional Widths.—*First:* Where the additional widt on one or both sides, and extends all the way through a t of land over which a right of way had previously been secu Fig. 17.

All that certain strip or parcel of land situate in the No east Quarter of Section One (1); Township One (1) North, Ra One (1) West of the Second Principal Meridian, in the Cou of...................., State of.......................
Described as follows, to wit:

A strip of land forty (40) feet in width over and across quarter section and lying adjacent to and on the Northerly of that certain strip of land conveyed by John Smith and to the..............Rail..........Company, by their D Dated.........................A.D........, Recorded in. Volume........Page......of the Deed Records of the Cou and State aforesaid, the strip of land hereby conveyed cont ing 1.226 acres, more or less.

NOTE.—The above method is very flexible and can be used ı nearly all cases where the U. S. Surveys exist, even when the dditional width does not extend all the way adjacent to the riginal tract, provided the end boundary lines are parallel with he Section Lines, by the introduction of the following clause

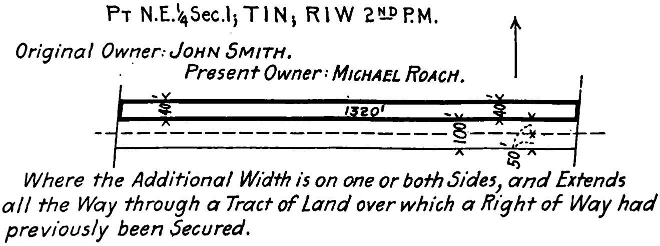

FIG. 17.—Additional Widths, Regular.

t the beginning of the descriptive notes: "A strip of land 40 eet in width extending from the East Line of said Quarter Section Westwardly........feet, and lying adjacent to and on the Northerly Line of that certain strip of land," etc.

Second.—Where the Additional Width is Trapezoidal or Irregular. Fig. 18.

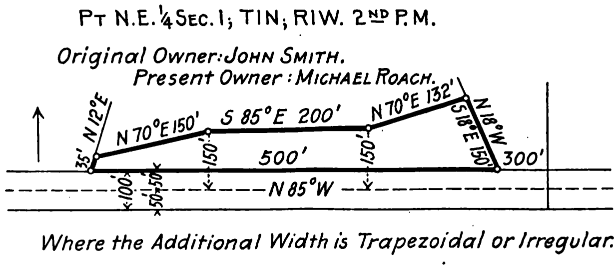

FIG. 18.—Additional Widths, Trapezoidal or Irregular.

All that certain strip or parcel of land situate in the Northast Quarter of Section One (1); Township One (1) North; Range One (1) West of the Second Principal Meridian, in the

County of................, State of........................,
Described as follows, to wit:

Beginning at a point on the Northerly Boundary Line of the present right of way of the......................Rail...... Company, distant therein 300 feet from the East line of said Quarter Section, and also distant Northerly 50 feet at right angles from the center line of the main track of said Railway as now constructed; Thence N. 85° W. 500 feet along said right of way line to the intersection of said line with the Grantor's Westerly Boundary line; Thence along Grantor's Westerly Boundary Line; N. 12° E. 35 feet; Thence N. 70° E. 150 feet to a point distant 150 feet Northwardly at right angles from the center line of main track aforesaid; Thence S. 85° E. 200 feet parallel with and 150 feet Northwardly from said center line; Thence N. 70° E. 132 feet to a point in Grantor's Easterly Boundary line; Thence S. 18° E. 150 feet along Grantor's Easterly Boundary line to the place of beginning, and containing an area of............Acres, more or less.

NOTE.—The above method is most generally used for all such cases; and is adaptable to surveys where curves and straight lines are involved, and whether the land is in United States Surveys or not.

10. City Property: Town Lots.—*First:* Lot or even Part of Lot. Fig. 19.

All that certain lot or parcel of ground situate in the City of...................., in the County of.................... State of.............. Described as follows, to wit:

The North 40 feet of lots, 9, 10, 11, 12, 13, 14, 15 and 16 in Block 17 of J. K. Brown's Sub-Division of the East Half of the Northeast Quarter of Section One (1); Township One (1) North; Range One (1) West of the Second Principal Meridian, Recorded in Plat Book, Vol.........Page.........., of the Plat Records of the County aforesaid.

NOTE.—The above is the simplest way of conveying lots. Where a part of a lot is conveyed, as for instance in Fig. A, the description may read, "The North 25 feet of the East 27.60 feet of Lot No. 1," etc.

Second.—Right of Way Cutting Across Lots. Fig. 20.
All that strip or parcel of land situate in the City of..........
the County of.................., State of.................
escribed as follows, to wit:

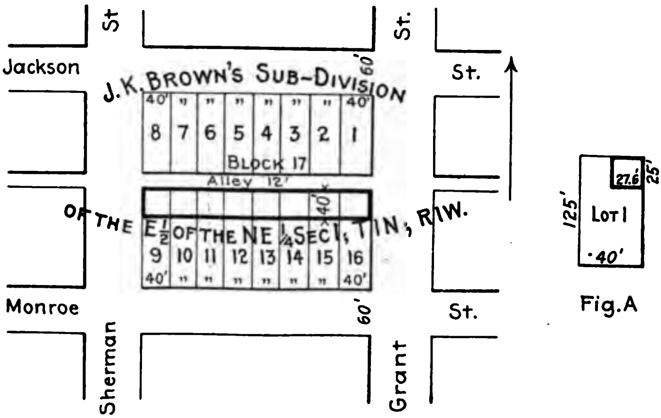

FIG. 19.—City Property. Lot or Even Part of Lot.

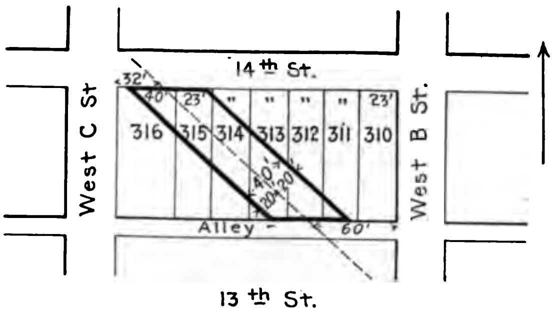

FIG. 20.—City Property. Right of Way Cutting Across Lots.

A strip of land 40 feet wide, 20 feet on each side of a center ne drawn across lots 311, 312, 313, 314, 315 and 316, in John ndre's Addition to the City of....................aforesaid;

said center line being more particularly described as follows: Beginning at a point in the North line of the Alley between 13th and 14th Streets in said Addition, distant 60 feet westwardly therein from the West line of West B Street; Thence in a straight line (or a curved line convex to the (N.E. or S.W.) having....feet for the radius) to a point in the South Line of 14th Street, distant 32 feet Eastwardly therein from the East Line of West C Street.

NOTE.—This method may be used for any single lot, so long as the center line description is used as shown above.

Writing Descriptions of Property to be Leased. Fig. 21.

11. First Class.—A strip of land situate in the town of....... County of.............., State of.........., Described as follows, to wit:

Beginning at a point 30 feet Southwardly at right angles from a point in the center line of main track of the................Rail ....Company, which is distant 150 feet Westwardly, therein from the West line of Main Street; Thence continuing Southwardly at right angles to said center line, 20 feet; Thence Westwardly parallel with said center line 60 feet; Thence Northwardly at right angles thereto 20 feet; Thence Eastwardly parallel with said center line 60 feet to the place of beginning, containing an area of 1200 square feet.

12. Second Class.—A certain lot of land in the City of........ ....County, State of.........., Described as follows, to wit:

Beginning at the Northwest corner of Main and Washington Streets; Thence Westwardly ,75 feet along Washington Street; Thence Northwardly 80 feet parallel with Main Street; Thence Eastwardly 75 feet parallel with Washington Street or Main Street; Thence Southwardly 80 feet along Main Street to the place of beginning, containing an area of 6000 square feet.

13. Third Class.—A certain piece of land situate in the City of ....County, State of................, Described as follows, to wit:

A rectangular piece of ground 16 feet by 40 feet, lying parallel with and 10 feet Northwardly from the center line of siding No. 15 of said Lessor Company, in the rear of its Station Building

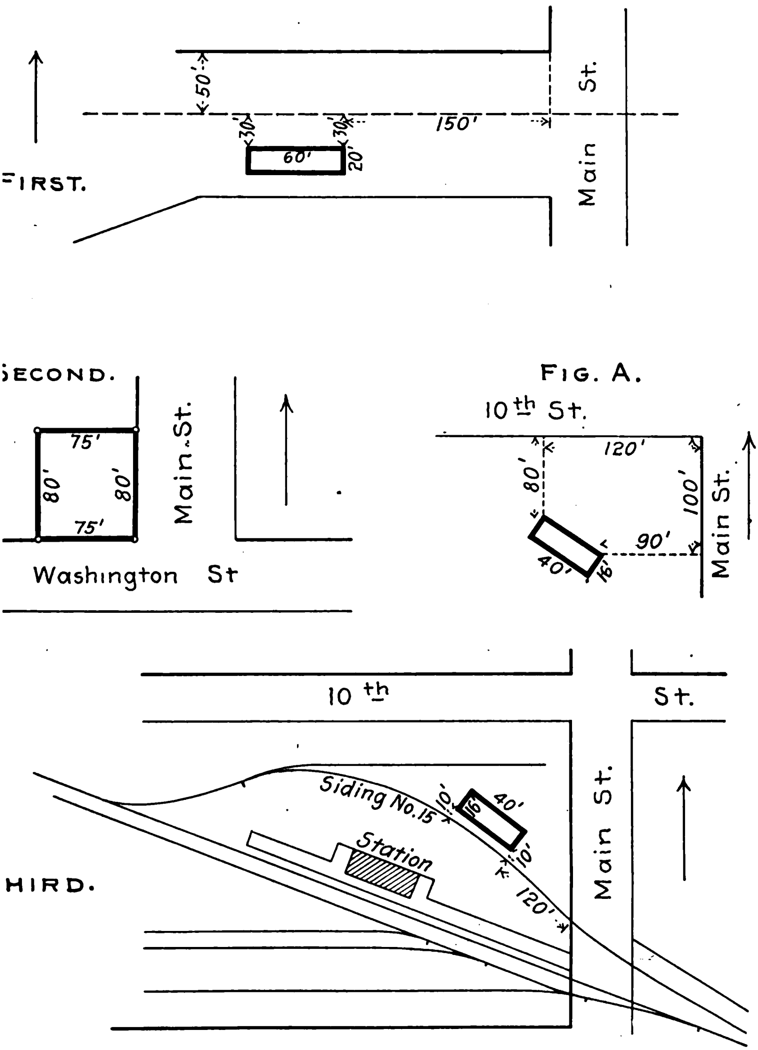

FIG. 21.—Leases.

in the said City, and distant 120 feet Northwardly measured along said siding No. 15 from the West line of Main Street, and containing an area of 640 square feet.

NOTE.—This latter form is not very desirable, but may be used where Tenancy at Will Leases are granted for privileges which are manifestly of the most temporary character, and where the tenancy of the ground is of no material importance, as far as precise location is concerned.

Where it is desired more definitely to locate the grant rectangular ordinates from property or street lines should be taken to two corners, and used in the description, as in Fig. A:

A rectangular piece of ground 16 feet Northeast and Southwest, by 40 feet Northwest and Southeast; The Northeast corner of which is 90 feet West of Main Street and 100 feet South of 10th Street, and the Northwest corner of which is 80 feet south of 10th Street and 120 feet West of Main Street; and contains an area of 640 square feet.

14. Purchase of Lands.—In making a statement of land to be purchased it is desirable to have an agreement with the owner which should accompany the report. A plat and description should also accompany the statement and the following information should be given in the report:

1. State with whom the agreement has been made, and, if the agreement is in writing, transmit it with the statement. All agreements should be made in writing, if at all possible, and no oral conditions, or promises, made, unless shown thereon.

2. Ascertain and state the names of all the owners, and their wives and husbands, by whom the deed is to be made, and their places of residence—town or township, county and state—and occupation; give the correct spelling of the names of the parties, and the initials, as they are to be signed to the deed, and if any party is an unmarried woman or man, widow or widower, state it. (This information must be full.) If a corporation give corporate name, place of business, names of President, Secretary and Treasurer, and name of State where incorporated. If any parties in interest are minors, state the age of each.

3. State to what Company, or individual, the deed is to be made; if individual, give residence and occupation.

4. State for what purpose the land is required; whether for new line

of railway, branch, additional tracks, side track, station, straightening, widening or otherwise. If authorized, quote the date and caption of the authority.

5. State whether the land is to be conveyed in fee absolutely, or merely right of way granted.

6. If the land is to be acquired for widening or straightening, state whether the owner agrees to include the old roadbed or right of way in the fee simple conveyance to be made.

7. State the price to be paid, total or per acre, and what amount, if any, has been paid on account.

8. Ascertain from the owner, and state whether the land is clear of all incumbrances, or what mortgages, judgments, or other liens, are against it; it must be agreed that all lines are to be removed.

9. State if any, and what, special covenants and conditions have been agreed upon relative to fences, crossings, right of carriage way, use of land, restrictions, or any other matter which should be mentioned in the deed.

10. Procure from the owner a memorandum of his title deeds, and state them here. If inherited, state from whom and when.

11. Ascertain and state if any tenant is on the land to be conveyed, and whether the tenant is to give up possession or is to remain as tenant; if to remain, state name of tenant, and terms of lease, and if the whole property leased is to be conveyed, the lease should be produced and transferred by the owner.

12. State any other matters relative to the land, or the purchase, necessary, or interesting to know. If any buildings are on the premises, describe them and given an estimate of their value. State whether or not the buildings are insured, and if insured, give a memorandum and description of the policies and advice whether policies will be transferred and assigned to the purchaser, or canceled. State if there are any special easements existing on or over the property.

An agreement of sale may be made by any person owning land in his or her own individual right, or by Executor or Trustee under a will or deed, if properly authorized by the will or deed. The husband of a married woman must join with her in making an agreement. An administrator of the estate of decedent, dying without a will, has no right to agree for, or sell, or convey land or right of way, but the land in such case descends to the heirs and widow or widower, and they must all agree to sell

and convey. Neither a guardian of minor children, nor an Executor or Trustee, who is not empowered by will or deed, has the right to sell, or convey, without special authority from the proper court; but they may make conditional agreements subject to approval by the court. In all such cases the proper explanations should be given.

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CHAPTER III

GRADING

15. Sections.—Fig. 22 shows the standard sections of the Pennsylvania Railroad. A sod line is not used and the sub-ballast, composed of a 12-in. layer of cinders, extends to the edge of the grade. In these plans the surface of the sub-grade is given a slope of $\frac{1}{4}$ in. per foot away from the center. Where any side track is parallel and adjacent to the main, the layer of sub-ballast is continued, forming the ballast for the side track. In this case, however, it is not extended to the edge of the grade, but the ballast ends a foot from the gauge line of the outside rail, the grade extending 3 ft. 6 in. beyond this to the ditch in cuts, and 4 ft. 6 in. to the edge of the bank in fills.

A sod line on the edge of the roadbed protects the grade and prevents erosion, besides presenting a very neat appearance. It is used by such roads as the New York Central, Pennsylvania Lines and Illinois Central, although some engineers object to it on the ground that it may retain water and prevent free drainage.

The American Railway Engineering Association considers that the track in excavation is placed upon what is virtually a low embankment, and in order to preserve uniformity of conditions immediately under the track throughout the line recommends that the width of sub-grade in excavations should be made the same as on embankments, outside of which sufficient room should be allowed for side ditches.

Where the character of the soil is poor, drains should be provided of vitrified pipe laid in trenches filled with broken stone or similar material. These should be laid to a depth of

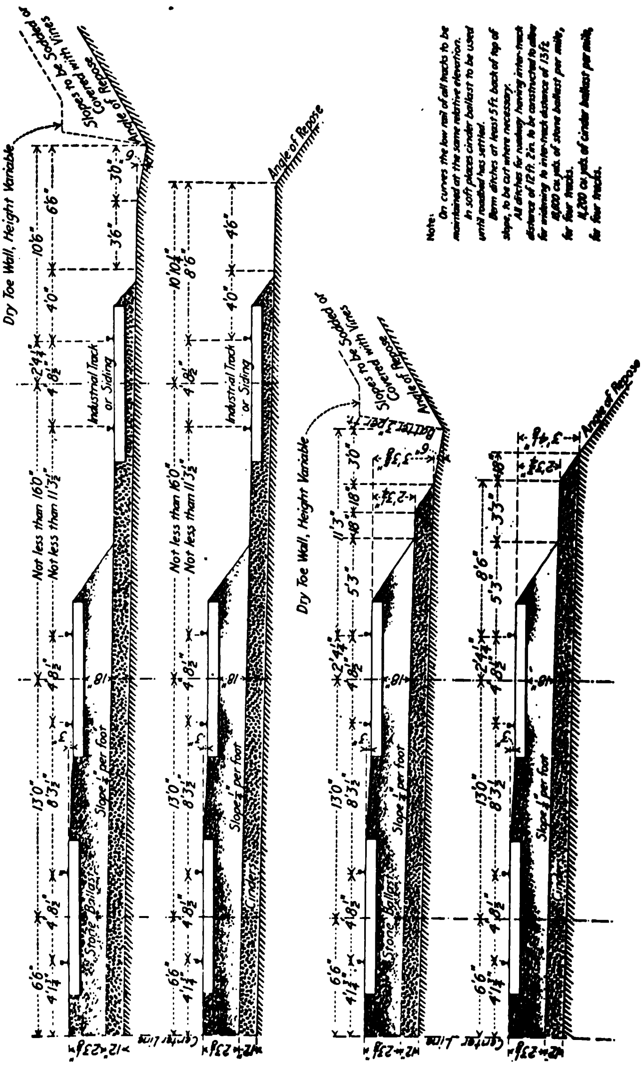

FIG. 22.—Four-track Roadway, Pennsylvania Railroad.

at least 3 ft. 6 ins. below the base of rail for ordinary bad material, and more if necessary, and empty into side ditches low enough to permit the drains to empty themselves freely.

16. Drainage.—One of the most difficult and important problems the maintenance of way engineer has to meet is the question of keeping water away from the track. In all cuts side ditches should be built large enough to carry off freely all the surface water and drainage that can come to them. The size required for these ditches will vary, depending upon the amount of water they will have to take care of, the rate of grade of the ditch, the character of the material in which it is dug, etc.

It is difficult to give any rule for the size of side ditches. Those shown on the sections of the Pennsylvania Roadbed, Fig. 22, represent the minimum size for average conditions of lengths of cuts, materials, grades, etc., the size to be increased when any of these conditions are unfavorable enough to require it.

In order to reduce the size of side ditches in cuts to reasonable dimensions, the water outside of the immediate grading should be taken care of independently to as great an extent as possible by surface ditches beyond the top of the slope. These are also of value in preventing sloughing of the slopes, which tend to fill up the side ditches, and as a further aid to this the slopes should be dressed and sodded.

When for similar reasons, surface ditches are necessary at the foot of the slopes of embankments, there should be provided a sufficient berm to prevent undermining the embankment or the sloughing of the slopes from filling the ditches. The slopes of fills should also be grassed or covered with material which will prevent to as great a degree as practicable their sloughing.

In bad cuts tiling of the ditches is frequently resorted to with excellent results. The tile best adapted to this purpose is ordinary farm tile, which may be laid in cinders and covered with marsh hay. On top of this the soil is filled in, the hay preventing the dirt entering the joints of the tile, the surrounding bed of cinders affording an opportunity for the water to get into the tile.

The side ditches should be kept clean and free from all obstructions which may interfere with the passage of the water. In cuts during the wet season the ditches frequently become filled with material which has been sloughed down from the sides of the cut. This was formerly removed by shoveling out and load-

FIG. 23.—American Railway Ditcher.

ing onto cars. Ditching machines are now quite generally used for this purpose and have greatly reduced the cost of handling this material, as well as enabling the work to be carried on in a much more expeditious manner than was possible when manual labor was employed.

These ditchers (Fig. 23) are small steam shovels running

ı a movable track placed on top of the flat cars which are to ɜ loaded.

The curves given in Fig. 24 show the estimated cost of hand-

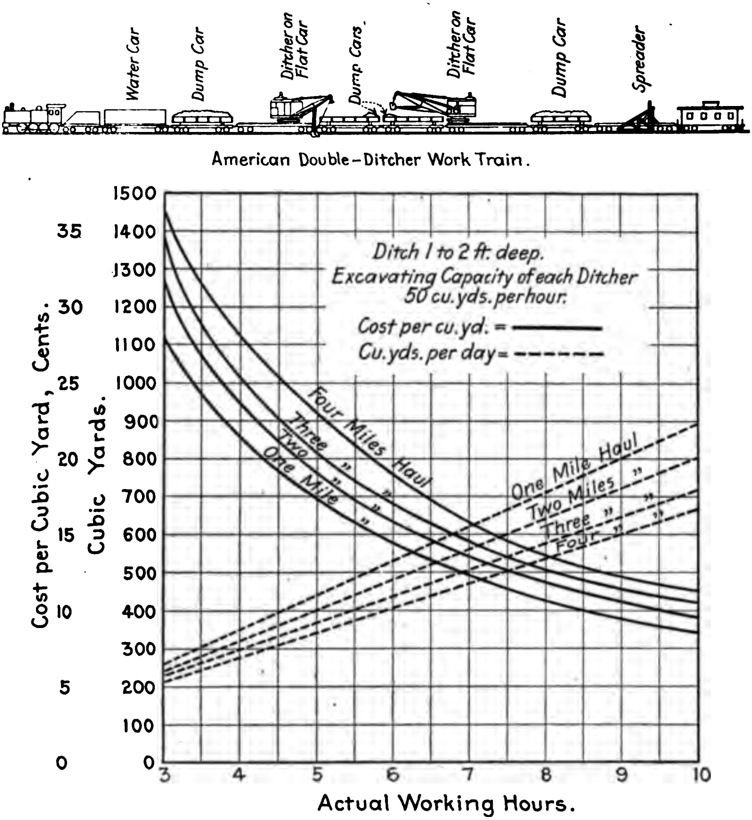

FIG. 24.—Cost of Handling Material with Double-Ditcher Train.

ng material with a double-ditcher train. As will be noted, the ɔst varies considerably, according to the number of hours the ıachine can work on the track undisturbed by other trains. 'he curves are based on the following data:

Daily Cost:

Two operators at $125 per month	$9.60
Two firemen	3.00
Interest on cars and ditchers	4.14
Depreciation on cars and ditchers	4.78
Oil, waste, etc	1.00
Coal	5.00
Locomotive coal, etc	15.00
Train crew	25.00
Repairs	2.00
Labor at $1.50 per day	6.00
	$75.52

Conditions.—Train—Four air dump cars, 80 cubic yards capacity, tw flat cars, one water car. Speed—20 miles per hour. Switch—2 miles run.

Even with well-proportioned side ditches it is desirable t carry the water under the track and away from the roadbe wherever it is possible to do so.

Slides seem in general to be caused by the action of wate although in some cases they may be due to the removal (material at the bottom of a slope or hill disturbing the equilibriu of the mass. The slide most commonly met with is that whe the earth moves on a bed of rock which has become wet an slippery. These are frequently of very large extent, as the Dry noch Slide on the Canadian Pacific Railway, which is abou 1500 ft. wide where it crosses the track and extends back int the hills for over 2 miles, the upper end of the slide being 2000 f above the track.

This slide closely resembles a glacier in action, being ver slow in movement, averaging only about 10 ft. per annum. Th probable cause is water saturating a stratum of clay over a smoot bed-rock.

The following description of a slide in a cut on the Cair Division of the Big Four is typical of the trouble experience in opening up new cuts. The cut was laid out with 1½ to 1 sid slopes and was protected, as was believed, from the injuriou effect of surface drainage by ample surface ditches. As the wor progressed it developed that the material consisted of a yello

clay resting on a blue slate rock. Shortly after the opening of traffic, heavy rainstorms occurred and the clay began to move, finally blocking traffic completely. To open the cut steam shovels were installed on each side of the cut on top and something over 175,000 cu.yd. of earth was removed. This relieved the pressure on the slide and no further trouble was experienced.*

17. Construction of the Roadbed.—Before the grading of the roadway is commenced, it is necessary to clear and grub the right of way if the line runs through timbered country. The specifications for the formation of the roadway recommended by the American Railway Engineering Association provide that †

> the right of way and station grounds, except any portions thereof that may be reserved, shall be cleared of all trees, brush and perishable materials which shall be burned or otherwise removed from the ground.
>
> Stumps of trees shall be cut close to the ground, not higher than the stump diameter for trees twelve (12) ins. and less in diameter, and not higher than eighteen (18) ins. for trees whose stump diameter exceeds twelve (12) ins., except between slope stakes of embankments, where stumps may be cut so that the depth of filling over them shall not be less than two and one-half (2½) ft.
>
> Stumps shall be grubbed entirely from all places where excavations occur, including ground from which material is to be borrowed. Grubbing is also required between the slope stakes of all embankments of less than two and one-half (2½) ft. in height.

The methods employed in grading the roadbed, while varying considerably to meet the character of the country through which the road runs, can be divided into two general classes which will cover most cases. First, where the material is handled by teams, and second where steam shovels are used. The first class is applicable where the quantities are small and the haul short, and the second in the case of heavy work and long hauls.

Considering first team work. On hauls of from 100 to 600 ft., the wheel scraper illustrated in Figs. 25 and 26 will move earth very cheaply, and with the larger sized scrapers earth can

* Proceedings Am. Ry. Eng. Assn., Vol. 10, Part 2, 1909, pp. 1023–1093.
† Manual 1911, pp. 21, 22.

be moved economically up to 1000 ft. under certain conditions. The scrapers should be used in gangs of ten to fifteen, according to the distance the material has to be hauled. The ground

FIG. 25.—Grading with Wheel Scrapers.

should be first plowed deep, one to three furrows being thrown one way. Beginning at the ends of the furrows, the operator should grasp the lever with one hand, throwing it forward, and

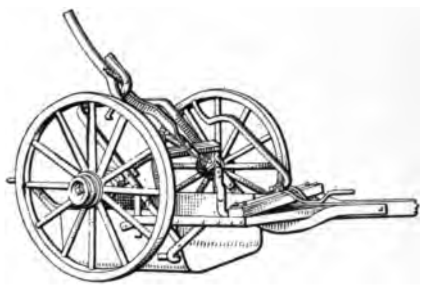

FIG. 26.—Western Wheel Scraper in Position to Load.

when the scraper is filled bear down on the lever until the latch catches on the scraper-pan. It is desirable to have an extra or snap team in the pit to assist in loading the larger scrapers holding one-half a yard or more.

The horses should be kept at a fast walk while the scraper is being dumped. On banks of 6 ft. or less it is customary to dump down hill over the end of the embankment. When the point of the pan reaches the end of the embankment, the back end of the pan is raised by the handle and lever until the point of the pan catches on the ground; the team will then pull it over.

Where the material is obtained from borrow pits alongside of the roadbed or in cuts where it is wasted with short hauls, and in fact for all conditions of very short haul, slip or drag scrapers are generally used. These are shown in Fig. 27.

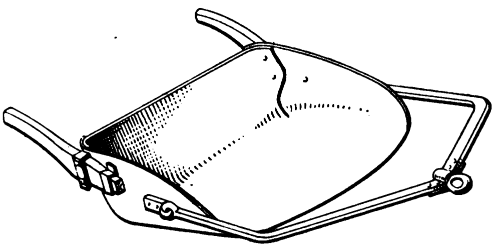

FIG. 27.—Western Slip or Drag Scraper.

For hauls too long to use scrapers to advantage it is necessary to employ wagons; these are generally of about $1\frac{1}{2}$ yds. capacity, and while formerly loaded by hand are now generally filled by elevating graders, as shown in Fig. 28. The graders are also sometimes used instead of the slip scrapers to excavate the material from side borrow and deposit it directly on the roadbed.

The steam shovel is a further step away from the scraper than the elevating grader. As shown in Fig. 29, the type generally used in railway work is mounted on standard-gauge trucks for ease in transportation.

When in operation the shovel works from its own track, which consists of short sections, and as the shovel digs its way through

the bank these sections are taken up from the rear and placed ahead of the shovel, thus providing a sufficient length of track for

FIG. 28.—Western Elevating Grader.

FIG. 29.—70 C Bucyrus Steam Shovel.

each move. The force required to operate the shovel consists of a pit gang of four or five laborers who lay the sections of

track and arrange the supports for the jack arms on the side of the shovel. These latter are screws working in two arms, one on each side of the shovel near the front. The lower part of the screw rests on wooden planks and steadies the shovel when digging.

On the shovel are two men, the engineer and the cranesman. The cranesman stands on a platform attached to the crane which revolves with it, and his duties are to control the dipper as it digs into the bank and dump it when the engineer swings it over the cars to be loaded.

Fig. 30.—Marion Steam Shovel in a Through Cut.

Steam shovel work may be roughly divided into two general classes. 1st, where the shovel widens out the grade without lowering it, Fig. 29, and 2d, where it is necessary to lower the grade, Fig. 30. In the first class a common case is where it is desired to widen an existing cut, as shown in Fig. 31. Here the shovel is cut into the side of the hill from the main track at *B* and digs its way through the cut, loading the material onto cars which are handled on the main line. The switch at *B* is generally left in, and as the shovel moves along, the track is extended. This gives the shovel a chance to back out of the way in case of

slides, and when long enough furnishes a track for the dirt train to get in the clear of trains on the main line.*

Fig. 32 illustrates the sequence of operations in lowering the grade in an existing cut. After the first cut is made the steam

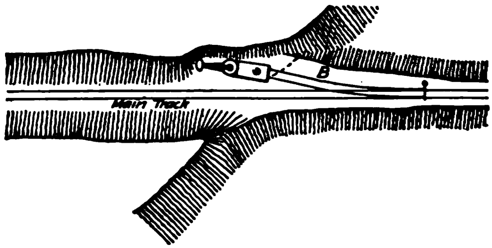

Fig. 31.—Steam Shovel Widening Cut. (Hermann.)

shovel track is used for the loading track for the second cut and so on until the excavation is down to the desired grade.

The output of the shovel depends largely upon the number of cars which can be supplied to it. If it is continually em-

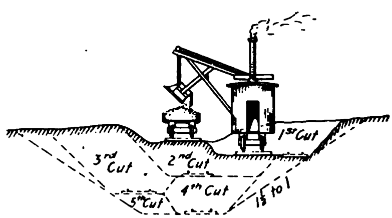

Fig. 32.—Steam Shovel Lowering Cut. (Hermann.)

ployed in loading, the output is large, especially when working in a bank of sufficient face not to require too frequent moving. On account of the long hauls of the cars before they are unloaded, especially if they are handled over the main track to the

* Steam Shovels and Steam Shovel Work. E. A. Hermann, 1894, Engineering News Publishing Co., New York, pp. 20 and 30.

dumping ground, the shovel is often idle a considerable part of the time waiting for cars and the full capacity is not reached.

In loading the cars a spotting engine is generally used at the pit to keep the cars delivered to the shovel. The spotting engine makes up the trains of loaded cars ready for the road engines and in general does the necessary switching at the pit tracks.

The cars used may be flat-bottom cars which are unloaded by a plow attached to a steel cable (Fig. 33). This cable is

FIG. 33.—Left Hand Bucyrus Side Plow at Work on the Erie Railroad.

connected to an unloading mill consisting of a drum for winding up the cable, or is fastened to the engine, which is disconnected from the train, the brakes set on the cars, and the engine pulls the plow over the cars. In place of flat cars, dump cars are now generally used, as shown in Figs. 34 and 105. These may be operated by air and the unloading of a train can be accomplished in a much more satisfactory manner than by means of a plow and cable, although when an unloading mill is employed the latter method loses many of its disadvantages.

The shovel generally employed in railway work is a 70- to 80-ton machine with a $2\frac{1}{2}$-yd. dipper. The dump cars for short hauls of less than a mile should have a capacity of about 6 yds.,

for longer hauls 12 yd. cars may be employed advantageously, and for hauls of considerable length cars of 20 or 30 yds. capacity will be found economical. Flat cars are generally standard-size cars with stakes set in the side pockets to guide the plow and provided with steel aprons between the cars to prevent the dirt getting on the track. The plow should weigh about 7 tons and when pulled by an engine and drum the latter should be able to develop a 60-ton pull.

In places away from the main line, as on revisions or new roads, the steam shovels usually load into narrow-gauge cars.

FIG. 34.—12-yd. Western Air-dump Cars Filling Trestle.

When the line remains unchanged but has to be widened for additional tracks, the material can be loaded into standard-gauge dump cars, and after being dumped is spread out by a spreader. These machines are shown in Fig. 35, and will spread for a distance of 17 ft. from the center of the track, leveling the grade so the track can be placed upon it without further work.

The wings of the spreader are operated by air supplied by the train pipe and can be readily adjusted to any height desired; in second-track work they are frequently used to level the ballast preparatory to placing the ties.

18. Construction Contract.—On account of the large magnitude of many of the works under the direction of the railway engineer, the contract which provides for their execution should be very carefully drawn up. On many roads this contract has been the result of growth, the earlier forms having clauses added to them from time to time as new conditions would arise.

To simplify and make uniform the different contract forms used throughout the country, a special committee was appointed on Uniform General Contract Forms by the American Railway Engineering Association. In working out a standard form, the

FIG. 35.—Mann-McCann Spreader.

committee first prepared a synopsis of all the necessary requirements and arranged them logically in skeleton form and then developed clauses around them in as simple and direct language as was possible.

The resulting form, while as concise as it could well be made, consistent with clearness and accuracy, was, nevertheless, quite large, and to provide for unimportant work the plan of having an agreement form of two pages separate from the general contract conditions was recommended. In small or unimportant contracts this agreement form may be used alone, but in larger contracts the "general conditions statement" may be inserted using the agreement form as a folder with the introductory page at the beginning of the contract and the signature at the end.

In addition to the contract conditions, specifications relating to the particular work should form part of the contract. These may either be included in the folder or attached to the back.*

19. Bearing Power of the Subgrade.—A knowledge of the bearing power of the roadway or subgrade is of a great deal of importance on account of the increasing tendency toward heavier loading of the track.

The influence of the character of the roadway is well shown by the following case reported by Mr. A. G. Wells, General Manager of the Atchison, Topeka & Santa Fe: †

> From Seligman to Barstow our track is laid with eighty-five-pound rails; the density of the traffic is practically the same over every foot of it. Between Yucca and Barstow, a distance of 227 miles, the subgrade is sandy, porous, and well drained; between Yucca and Seligman, a distance of 91 miles, the subgrade is largely clay, of a kind that holds water. From November, 1907, to October, 1908, we had eighty-three rail breakages on the territory first named, or a percentage of .001; on the other stretch we had in the same period seventy-two breakages, the percentage being .0025, or, in other words, where the subgrade was dense and more or less clay, the breakages per mile were two and one-half times greater than where the subgrade was sandy.

The inertia of the roadbed plays an important part in strengthening the track when the maximum loads imposed upon it do not occur too frequently, as is the case with high-speed passenger trains where the most destructive forces to be provided for are those produced by the drivers of the locomotive. In the case of dense freight traffic where the heavy loads imposed by the engine drivers are followed by the passage of a long train, thus subjecting the track to a continuing load lasting over a considerable interval of time, the inertia of the roadbed is, in a great measure, overcome and a correspondingly lower value for the allowable pressure on the roadbed must be used.

The all-steel 70-ton coal cars, which are coming into use on some of the large coal-carrying roads in the East, weigh over

* See references in bibliography at end of chapter.

† Railroad Age Gazette, April 9, 1909.

50,000 lbs., and have a capacity of 140,000 lbs. This weight is carried on four axles, and a train composed of these cars would prove very destructive to the roadbed unless an ample provision was made for the effect of the repeated application of the heavy wheel loads.

The bearing power of the subgrade is such an important factor in proportioning the track that it will prove profitable to examine what takes place when the soil is subjected to pressure.

The bearing power depends upon the angle of repose. When this is not known it may be determined by the following test, suggested by the Committee on Roadway of the American Railway Engineering Association.*

Measure the force required to cause slipping of two portions of the earth past each other when subjected to a known pressure, and,

$$\tan \phi = \frac{Q}{P},$$

where ϕ = angle of repose;

Q = force required to cause slipping;

P = pressure on earth.

Earth which has an angle of repose of at least 27 degrees may be considered as firm. Sand, gravel and damp clay are classed as firm soils; however, these may become so saturated with water that their angles of repose will become considerably less than 27 degrees, hence precaution must be taken against too much water by draining the ground in the immediate vicinity of the roadbed. Particular care must be taken in the case of clay, or sand which will become a kind of quicksand when saturated with water.

The water which destroys the bearing power of such soils may come from below by capillary attraction, and the drainage should be carried to a depth sufficient to prevent this. Semi-

* Proceedings, Vol. 13, 1912, p. 295.

fluid soils, such as quicksand, alluvium, etc., should be removed where practicable or the foundation carried to a lower stratum.

If in Fig. 36 we let

x = depth of ballast (from top of tie to subgrade);

p = maximum supporting power per sq. ft. of the subgrade;

p_1 = pressure exerted on subgrade midway between ties;

γ = weight of 1 cu. ft. of ballast;

ϕ = angle of repose of subgrade;

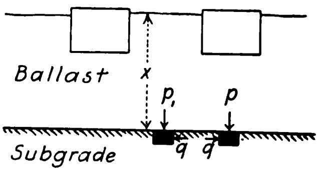

FIG. 36.—Resistance of Sub-grade to Pressure of the Track.

$x\gamma$ will then equal the vertical intensity of the pressure caused by the weight of the ballast on the subgrade midway between the ties. This pressure is augmented by the pressure transmitted from the tie, and, while this is much less between the ties than immediately underneath a tie, it is, nevertheless, an important factor in strengthening the surface of the roadbed.

If we assume this extra pressure on the roadbed midway between the ties to equal in amount that caused by the weight of the ballast, we can then write

$$p_1 = 2\gamma\, x$$

Now when the ballast is about to sink:

$$\frac{p}{q} = \frac{1+\sin\phi}{1-\sin\phi} \quad \text{or} \quad q = p\frac{1-\sin\phi}{1+\sin\phi}. \qquad \text{(Rankine)}$$

But when the roadbed under the tie is on the point of sinking

part of the roadbed between the ties must be on the point of
ıg, or

$$\frac{q}{p_1}=\frac{1+\sin\phi}{1-\sin\phi},$$

the supporting power of the subgrade or p is

$$p=p_1\left\{\frac{1+\sin\phi}{1-\sin\phi}\right\}^2=2\gamma x\left\{\frac{1+\sin\phi}{1-\sin\phi}\right\}^2$$

$$\imath=q=p\frac{1-\sin\phi}{1+\sin\phi}=p_1\frac{1+\sin\phi}{1-\sin\phi};\quad p=p_1\left(\frac{1+\sin\phi}{1-\sin\phi}\right)\left(\frac{1+\sin\phi}{1-\sin\phi}\right)\Big].$$

For convenience the values of $\left\{\frac{1+\sin\phi}{1-\sin\phi}\right\}^2$ are given in
ıle III and for γ in Table IV.

This apparently would be a safe assumption for a depth of
ʼel ballast under the tie of 18 ins. and 12 ins. of stone.

TABLE III

VALUES OF $\left\{\frac{1+\sin\phi}{1-\sin\phi}\right\}^2$

ϕ.	$\left\{\frac{1+\sin\phi}{1-\sin\phi}\right\}^2$.	ϕ.	$\left\{\frac{1+\sin\phi}{1-\sin\phi}\right\}^2$.
10	2.0	26	6.6
11	2.2	27	7.1
12	2.3	28	7.7
13	2.5	29	8.3
14	2.7	30	9.0
15	2.9	31	9.7
16	3.1	32	10.6
17	3.3	33	11.5
18	3.6	34	12.5
19	3.9	35	13.6
20	4.2	36	14.8
21	4.5	37	16.2
22	4.8	38	17.6
23	5.2	39	19.4
24	5.7	40	21.2
25	6.1		

TABLE IV

WEIGHTS OF BALLAST

Values of γ

Name of Ballast.	Average Weight, in Pounds per Cubic Foot.
Gravel..................	90 to 105
Sand....................	90 to 105
Sand perfectly wet........	120 to 130
Stone, crushed...........	90 to 110

It can be readily seen that as the depth of the ballast increases the value of p_1 increases quite rapidly both on account of the actual greater weight of the ballast represented by the term $x\gamma$, and also by the better distribution of the tie pressure. Each of these factors tends to prevent the rising of the subgrade between the ties and thus increases the supporting power of the soil under the tie.

If we assume that the value of p is 1.0 to 1.5 tons per square foot, by applying the above formula we find that this corresponds to a soil with an angle of repose of from 23 degrees to 31 degrees for 12 ins. of stone ballast or 18 ins. of gravel ballast under the tie. Rankine's tables show that these angles of repose fall within the limits given for dry sand, clay and mixed earth. This agrees very well with what might be expected. The principal value of the formulæ, however, would appear to lie in comparative rather than in actual values.*

In estimating the bearing power of the subgrade, it should be borne in mind that the resistance is very much lowered if the ballast is allowed to penetrate and mix with the soil, as is the case when stone or crushed slag are placed directly on a soft subgrade without the use of a proper layer of sub-ballast of gravel or cinders. (Refer to Fig. 106.)

* Compare with discussion of bearing power of soils in Retaining Walls for Earth, M. A. Howe, 1896, John Wiley & Sons, New York, p. 37.

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CHAPTER IV

BRIDGES, TRESTLES AND CULVERTS

20. Masonry Culverts.—The most satisfactory construction for small main line openings above a 4-ft. span is generally the reinforced concrete arch culvert. The standard design of the Pennsylvania Railroad for these culverts having spans from 4 to 10 ft. is shown in Fig. 37 and consists of an elliptical section in which the bottom of the culvert or the bed of the stream has a radius equal to the span, and the sides start with the same radius, drawing in to a smaller radius at the top.

Fig. 38 shows a section of a reinforced concrete culvert at Kilton on the North Eastern Railway. This culvert is 435 ft. in length, of which 275 ft. in the middle is of the section shown. Toward the end the thickness at the crown diminishes 2 ins. at a time to 12 ins. at the inlet and outlet, and the thickness at X similarly diminishes to 1 ft. 9 ins. at the ends.*

21. Pile and Frame Trestles.—There are two general kinds of wooden trestle bridges: the pile trestle, in which the bents consist of piles, and the frame trestle with the bents composed of square timbers framed together. The pile trestle is not suitable for heights above 30 or 35 ft., but framed trestles may be constructed to much greater heights.

In the earlier days of railroad building the mileage of wooden trestles in this country was very large and Cooper states †

that the relative amount of bridges and trestles varies (1889) in different districts from 58 ft. per mile to 231 ft. per mile. This, last,

* Reinforced Concrete Railway Structures, J. D. W. Ball, 1914, D. Van Nostrand Co., New York, p. 181.

† American Railroad Bridges, Theodore Cooper, Trans. Am. Soc. of Civil Engrs., July, 1889. Vol. XXI, p. 44.

however, is excessive, from including the crossing of Lake Pontchartrain near New Orleans, on a trestle 22 miles long. Omitting this, we would get only 162 ft. per mile as a maximum.

The use of these temporary structures was one of the characteristics of American railway construction at that period and enabled the large amount of new lines to be completed at a much cheaper cost and more rapidly than would otherwise have been

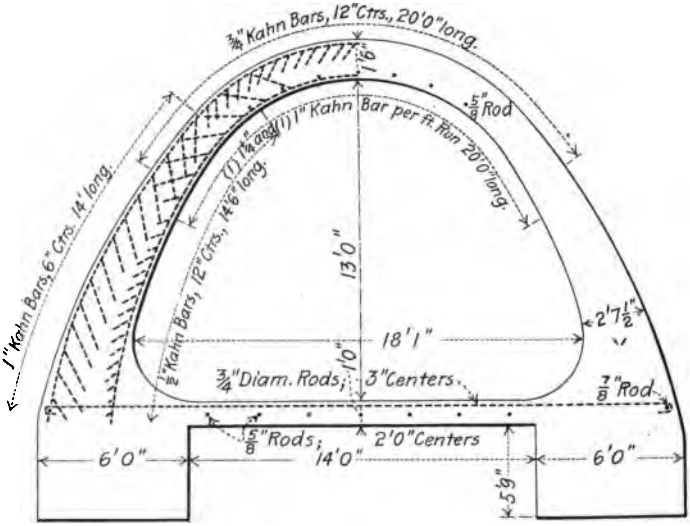


FIG. 38.—Kilton Culvert, North Eastern Railway. (Ball.)

possible. As an instance of this may be cited the construction of the Canadian Pacific Railway. This company made a contract with the Canadian government on October 21, 1880, to complete the line to the Pacific Coast in ten years, but owing to the large amount of temporary work employed the company was enabled to open its line from the St. Lawrence River to the Pacific Coast in November, 1885, and to earn $20,000,000 in the year fixed for the completion of the contract.*

* Engineering News, Nov. 28, 1895.

While the use of wooden trestles is not as common as was formerly the case, this kind of bridge is still largely used on lines having light traffic, and probably will continue to be used for some time.

Fig. 39 illustrates the standard trestle used on the Pennsylvania Railroad. Many variations from this design are found on different roads. Eight stringers, 8×16 ins., four under each rail, are sometimes used. Some roads use ties 12 or 14 ft. long, and place jack stringers 8×16 ins. near the end of the ties; 18-in. I-beams, three under each rail, are used to replace the wooden stringers on one road.

The double cap, one cap being placed on top of another, is considered good practice by some engineers, and the use of a corbel between the cap and the stringer has been employed.

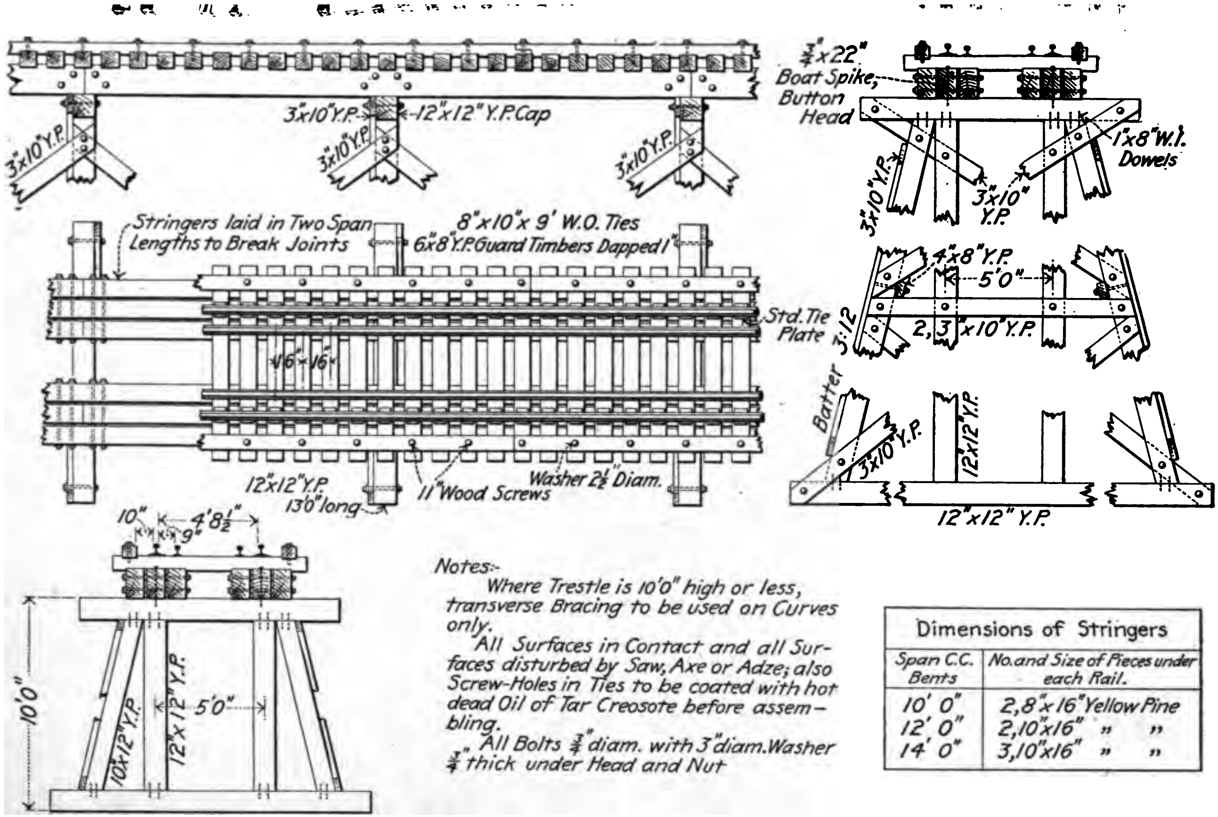
One of the principal objections to the wooden trestle is the danger of fire being started on the bridge from sparks or coals from locomotives. The Railway Commission of Canada require that railroads fireproof their bridges, and order

> That every railway company subject to the legislative authority of the parliament of Canada operating by steam power any railway or railways, any part or parts of which is or are constructed of, or upon, wooden trestles, the whole of which cannot be seen from an approaching train for a distance of at least one thousand feet, do, during the months of May, June, July, August, September and October of each year, provide, place and keep a watchman, trackwalker, fire alarm signals, ballast flooring, zinc covering over caps and intersections, or approved fireproof paint, as hereinafter directed, for the purpose of protecting the said trestles from fire; each said company having the option of adopting any of the said foregoing methods of protection.

The American Railway Bridge and Building Association gives the following as the types of fireproofing used mostly at the present time:

A. Ballast floor pile bridges; about the same amount of ballast being placed under the tie on bridges as on an embankment.

B. Metal covering on the ties.



Notes:-

Where Trestle is 10'0" high or less, transverse Bracing to be used on Curves only.

All Surfaces in Contact and all Surfaces disturbed by Saw, Axe or Adze; also Screw-Holes in Ties to be coated with hot dead Oil of Tar Creosote before assembling.

All Bolts ¾" diam. with 3" diam. Washer ¼" thick under Head and Nut

Dimensions of Stringers	
Span C.C. Bents	No. and Size of Pieces under each Rail.
10' 0"	2,8"x16" Yellow Pine
12' 0"	2,10"x16" " "
14' 0"	3,10"x16" " "

FIG. 39.—Standard Trestle, Pennsylvania Railroad.

C. Ballast covering from 2 to 4 ins. thick on the ties; a wood filler being placed between the ties to support the ballast.

D. Metal covering on the caps and stringers.

E. Metal covering on the ties with 2 ins. of ballast thereon.

F. Ordinary pile bridges built with certain kinds of treated timber.

G. Fire-resisting paints.

H. Pile bridges having I-beam stringers.

22. Concrete Trestles.—In railroad construction in the West and South, it was, and is still quite generally the practice to bridge unimportant streams, bayous and marshes with timber or pile

Fig. 40.—Concrete Trestle.

trestles. As the cost of timber increases and as the standards of the line are raised, these structures have been replaced with more permanent work. There are, however, many cases in this territory of long timber trestles over river bottoms and swamps where it is not practicable to replace the trestles with more permanent steel bridges on account of their expense.

These conditions have apparently been met successfully by the use of a concrete trestle (Fig. 40) following closely the main features of the timber trestle, using concrete piles and reinforced concrete stringers.

This type of pile trestle was first designed by Mr. Cartlidge and has been in use on the Chicago, Burlington and Quincy Railroad long enough to warrant the view that it is a durable and

satisfactory form of construction. It apparently may be used to replace wooden trestles of low and medium height where the features of short span and adaptation to ground slope are advantageous, and where conditions will otherwise warrant the expenditure.*

23. Pipe Culverts.—Cast-iron pipe was formerly very largely employed for small openings. The principal objections to this pipe are first of all its weight, which makes the expense of handling high, especially on new lines where it may have to be hauled by teams for considerable distances, and second the fact that under high fills, unless very firmly supported, many pipes crack and break.

The advantage lies in the fact that it will not depreciate and will last indefinitely when properly placed and not subjected to excessive loading.

This pipe is now sometimes made in 3- and 4-ft. sections for greater ease of handling in place of the former 12-ft. sections. These smaller sections have interlocking joints, which gives practically a continuous tube construction.

Corrugated metal culverts (Fig. 41), are now being used extensively for small openings under light railways. The nestable construction of these culverts makes their transportation easy, and the use of the corrugated metal gives relatively high strength for the weight of metal used. Steel on account of its liability to rust cannot be used successfully for this purpose, and it is necessary to use wrought iron or some metal having non-corrosive qualities.

Probably one of the greatest advantages of the corrugated culvert is the ability of these pipes to maintain a clear waterway under a settling or shifting embankment. In the construction of the Northwestern Pacific these pipes were used and in one case of a 48-in. pipe which moved down hill, four 10-ft. lengths were added to the upper end.†

Reinforced concrete culvert pipe is coming into favor in places

* Reinforced Concrete Trestles for Railways, C. H. Cartlidge, from Journal of the Western Society of Engineers, Vol. XV, No. 5, October, 1910.

† Railway Age Gazette, Feb. 19, 1915, p. 317.

FIG. 41.—Corrugated Metal Culverts.
A. Transporting by Teams 60-in. Culvert 40 ft. Long.

FIG. 41.—Corrugated Metal Culverts.
(Ry. Age Gazette.)
B. 60-in. Culvert under an 85-ft. Fill on the Western Pacific.

where a more permanent construction is desired than that obtained with corrugated metal.

Where small culverts are to be built, the miscellaneous expense, such as building material platforms, cement sheds, unloading tools and material, etc., constitutes a large proportion of the cost. The greater portion of this is avoided if concrete pipe be used.

The cost of reinforced concrete culvert pipe will vary in different localities, depending upon the proximity of the natural supplies of material and the cost of labor. Under ordinary conditions, however, there is a considerable saving over the cost of cast iron, especially in the larger sizes, where the saving may be from one-third to one-half.

The American Railway Bridge and Building Association give the following relative costs per lineal foot with

cast iron at $28.00 per ton and the market quotations for manufactured concrete pipe. It will be noted that the economy is more marked with an increase in diameter of the pipe.

	24 in.	30 in.	36 in.	48 in.
Cast iron......	$2.23	$3.33	$4.66	$8.26
Concrete......	2.00	2.80	3.15	4.50

Fig. 42 shows the reinforcement used in the C. B. & Q. pipe. This road has been using reinforced concrete pipe for about

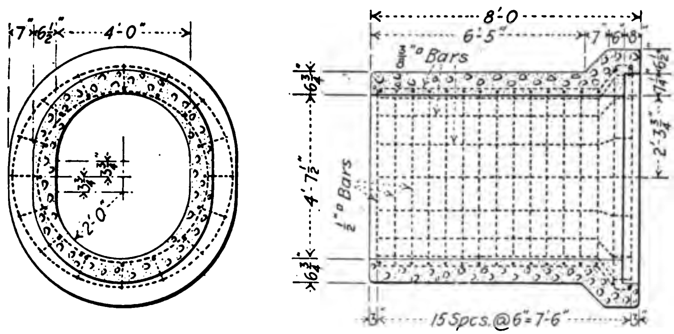


FIG. 42.—Reinforced Concrete Culvert Pipe, C. R. I. & P. Ry. and C. B. & Q. R. R. (Am. Ry. B. & B. Assn.)

eight years, and are constantly increasing their output of this kind of culvert pipe. The sizes used run from 2 ft. to 6 ft. in diameter.

24. Waterway.—Fig. 43 shows the form of record for waterways recommended by the American Railway Engineering Association. The Association gives the following rules for fixing the size of the opening:*

1. In determining the size of a given waterway, careful consideration should be given to local conditions, including flood

* Manual, 1911, p. 40.

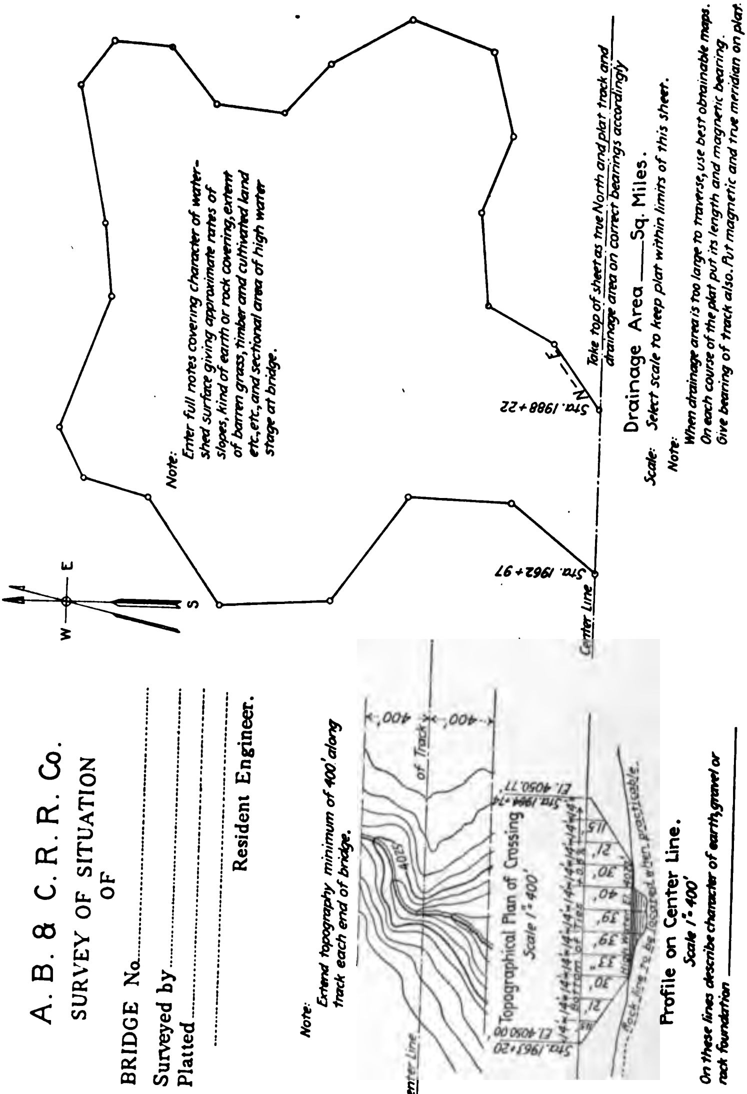


FIG. 43.—Field Observations Necessary for Determining Size of Waterways. (Am. Ry. Eng. Assn.)

height and flow, size and behavior of other openings in the vicinity carrying the same stream, characteristics of the channel and of the watershed area, climatic conditions, extent and character of traffic on the given line of railway and probable consequences of interruptions to same, and any other elements likely to affect the safety or economical construction or maintenance of the culvert or opening.

2. (*a*) The practice of using a formula to assist in fixing the proper size of the waterway in a given case is warranted to the extent that the formula and the values of the terms substituted therein are known to fit local conditions.

(*b*) Waterway formulæ are also useful as a guide in fixing or verifying bridge and culver tareas, where only general information as to local conditions is at hand.

(*c*) The use of such formulæ should not displace careful field observation and the exercise of intelligent judgment on the part of the engineer.

(*d*) No single waterway formula can be recommended as fitting all conditions of practice.

In the design of culverts under the tracks, provision is rarely made for those unusual storms which only occur after long intervals, and in consequence structures which may have stood successfully for forty or fifty years are at times washed out. Nor is this necessarily evidence of poor engineering skill on the part of the builders of the road, as to construct these openings of sufficient capacity to insure against the possibility of their ever being destroyed by water would in many cases result in an expense entirely out of proportion to the loss caused by their being washed out. If, for example, we assume that a culvert may be built for $2000 which would resist any possible flood, but instead of doing this a culvert of smaller capacity was actually built costing $1000 and which lasted for forty or fifty years, it will be seen that the compound interest at 6 per cent on the money saved would amount to something over $18,000 in this time. Wellington states in this connection:*

* Economics and Theory of Railway Location, A. M. Wellington, 1900, John Wiley & Sons, New York, p. 782.

When structures have been skilfully laid out to stand the ordinary contingencies of 20 or 30 years it is about all that is either practicable or justifiable, and the remarkable storms which come only once or twice in a century are not in fact, and hardly can be successfully guarded against. This is especially true because the worst effects of even the greatest storms are localized within quite narrow limits. The same is, in substance, true of inundations of railway lines.

The most disastrous floods of recent years were those which occurred during the spring of 1913, in Indiana, Ohio and the neighboring States. A great many of the roads in this territory were built over fifty years ago, and in spite of the great damage done, which in the State of Ohio alone was estimated at $10,000,000, it would not appear that the roads could have been economically located in the first place to withstand these extraordinary floods which occurred only after a period of half a century.

It will be observed that only about $500,000 could have profitably been spent at the time the roads were built, in the way of larger openings and a higher grade line, to guard against the floods which occurred fifty years afterwards with the damage of $10,000,000, and it is quite improbable that this comparatively small sum would have been sufficient to enable the roads to be constructed to withstand the 1913 floods.

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CHAPTER V

TIES

25. Forms of.—Three methods of supporting the rail have been employed.

First.—The longitudinal or stringer.

Second.—The pedestal.

Third.—The cross-tie.

The rail used in the early days of the railroads consisted of a thin strip of metal, and as this was not strong enough to carry the wheels unsupported it was necessary to carry the running strips upon stringers, which were generally of wood. As the rail increased in section, pedestal supports were tried. The rails of that time were cast in sections about 3 ft. long and rested on stone blocks. In some countries pedestal support is still used and there is a considerable mileage of track in British India and in the Argentine Republic supported on large cast-iron inverted bowls connected together with tie rods at right angles to the track. The Kimbal concrete tie, described in Article 27, is a form of pedestal support recently tried in this country.

With pedestal support the distribution of pressure from the rail to the subgrade is obviously not as uniform as with the cross-tie support; and for this reason, principally, pedestals are not adaptable for use under modern track conditions.

Longitudinal stringers or girders under the rail have been tried with the idea of obtaining a better distribution of the load to the grade.

The most recent experiments on longitudinal support in this country were those conducted by Gustav Lindenthal with the system of track shown in Fig. 44. This was installed at

Pomeroy, Pa., on the Pennsylvania Railroad, in 1906, and was under test for about two years.

The rail joints were in the middle of each stringer length and it was expected that the stiffness of the sleepers would in that way prevent low rail joints, but this was found not to be the case and the track and all of the joints got low.

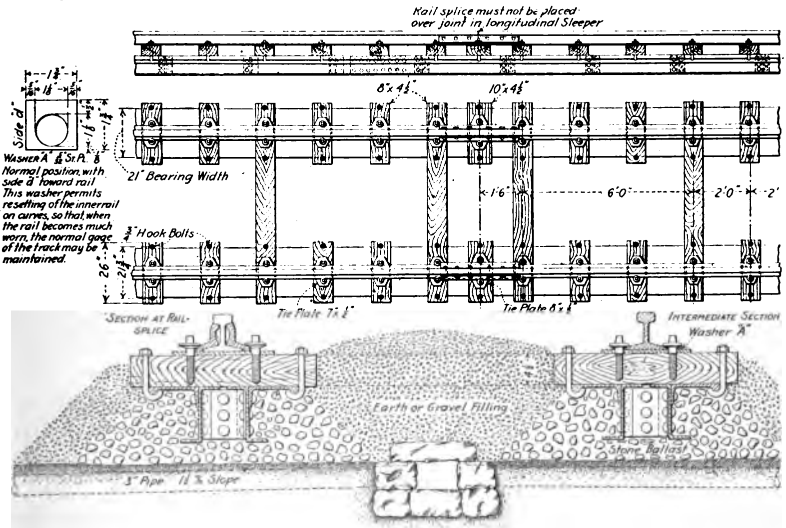

FIG. 44.—Lindenthal's Longitudinal Method of Rail Support.

The explanation for it was that the blows from locomotives and cars at the rail joints gradually hammered down the railroad sleepers. These being very stiff, could not very well be bent back and straightened by merely tamping at the low places. In ordinary cross-tie track the rails are easily kept to the surface by tamping the ties harder at the rail joint. But the same method was not effective with longitudinal sleepers, which would sag more and more in spite of all ordinary attempts to surface them. Looking at the track (about 1000 ft. long) lengthwise,

the low rail joints were quite conspicuous. While the sleeper track as a whole was singularly free from the pumping and wave action observable in ordinary cross-tie track, the indications were that the stone ballast under the middle of the sleepers would have to acquire considerable rigidity by continuous tamping before the rail ends would stay surfaced.

The extensive experiments undertaken in Germany on longitudinal track systems have been attended with much the same results as those observed in the Pennsylvania test; and the conclusion arrived at from these experiments, that the longitudinal sleeper offers no advantage over the system of cross-ties and rails, may be considered as firmly established.

The cross-tie track is now almost universally used, and in the opinion of those best qualified to judge no change is likely to occur from this method of rail support.

26. Metal Ties.—From an early date various forms of metal cross-ties have been suggested, and a large number of steel ties have been tried in different countries.

These are of two general types, the trough and the I-beam section. The latter seems better suited for heavy loads, and most of the steel ties used in this county are of the I-beam type, illustrated in Fig. 45. These ties cost about $2.50 each, complete with fastenings, and have a scrap value of about $0.75.

Steel ties have been used quite extensively on the Union Railroad at Pittsburgh and on the Bessemer and Lake Erie Railroad. The total number of steel ties on these two roads is over one million, or enough to lay over 300 miles of track. There are a large number of steel ties of the Carnegie type in use through the country. The Carnegie Steel Co. has manufactured three million steel ties, which are in use on twenty different roads. The difficulties of obtaining a satisfactory fastening of the rail to the tie, the insulation of the rails where automatic signals are used, and the question of deterioration due to rust, all seem in a fair way of being solved successfully, and the principal criticism raised against the steel tie is its rigidity as compared to the wood cross-tie.

The Bessemer officials, however, state that their experience

has led them to believe that this greater rigidity is not detrimental and is, in fact, something to be desired.

On lines with heavy refrigerator traffic the loss due to corrosion should prove heavier than on the Bessemer and Lake Erie. To protect against this corrosion the manufacturers in some instances dip the ties in hot tar at an additional cost of about five cents per tie.

It is quite probable that the life of these ties will be determined by the strength of the upper flange. This flange is subjected to a large number of alternate repeated stresses. As the

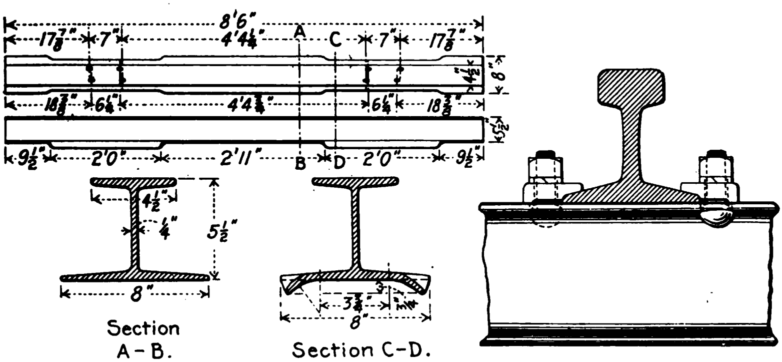

FIG. 45.—Carnegie Steel Tie.

wheels pass over the rail the load tends to bend the flange downward on the side of the tie from which the wheel approaches, and then after the wheel passes over the tie to bend the flange in the opposite direction. In the new design for the Pennsylvania an effort has been made to strengthen the tie at this point by increasing the radius of the fillet connecting the upper flange with the web.

Fig. 46 is a view of the Bessemer and Lake Erie track laid with steel ties.

27. Concrete Ties.—Probably no form of reinforced concrete tie has been made which is suitable for heavy and high-speed

traffic. The real field of usefulness for the concrete tie appears to lie in its application in places where speed is slow and where conditions are especially adverse to the life of wood or metal.

The Kimbal concrete tie illustrated in Fig. 47 is composed of two blocks of concrete, one under each rail, connected by means of a heavy iron bar. Placed on top of each block of concrete is a block of wood upon which rests the rail. The wood blocks serve the double purpose of affording an elastic cushion for the rail and as a means of spiking the rail to the tie.

Concrete ties do not seem to possess sufficient elasticity to absorb the shocks of the wheels and have a tendency to dis-

Fig. 46.—Track Laid with Steel Ties.

integrate under traffic. This has led to a modification of these ties in which the concrete is encased in a steel shell. Two designs of this latter type have been experimented with, the Riegler tie, fifteen of which were put in the main track of the Pennsylvania Lines, in May, 1908, where they are subject to very heavy traffic and are apparently giving satisfactory service; and the Atwood steel tie. Several of the Atwood ties were installed on the Pittsburgh and Lake Erie Railroad in October, 1908. These gave good results, but suggested some improvements in design. Fig. 48 shows the most recent design of the Atwood tie.

This tie is not strictly a concrete tie. Mr. Atwood states:*

The fact that concrete is used as a filler and to keep the two portions of the steel tie in alignment and to gauge does not constitute this a concrete tie. A tie is for the purpose of supporting the load that is transferred to it through the rails. The concrete filler in this tie is not called upon to carry this load; the load is carried entirely by the steel portions

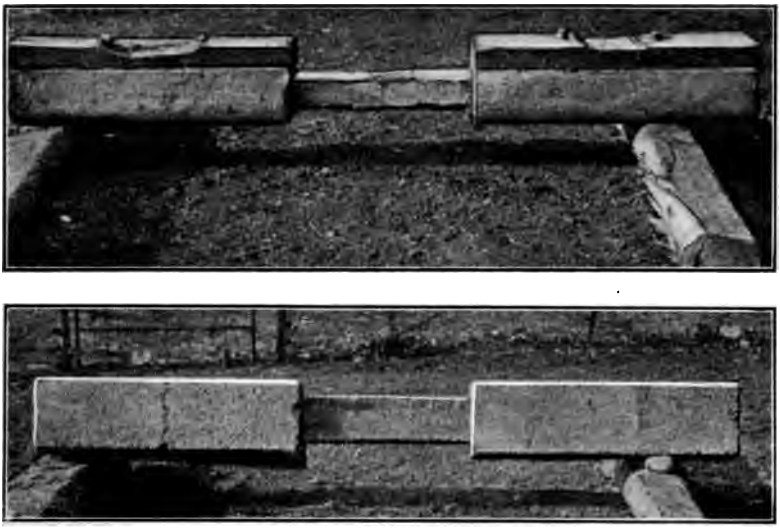

FIG. 47.—Kimbal Tie.

of the tie, which are made of ample dimensions for that purpose. The concrete in the tie is not subjected to stresses which concrete ties are called upon to bear. That is the reason that the concrete in the ties in use on the P. & L. E. R. R. is still as good as it was five years ago, when first put into service.

28. Wood Ties, Production of.†—Ties were formerly nearly always split and were usually made out of heartwood, using the best, and only straight live trees.

* Private communication, Dec. 15, 1914.
† From Reports of the Forestry Service and Bureau of the Census.

There is probably no other branch of the lumber industry in which so many small trees are annually destroyed and the possible regrowth of forests retarded to such an extent as in the manufacture of ties. The practice of sawing ties from logs is going

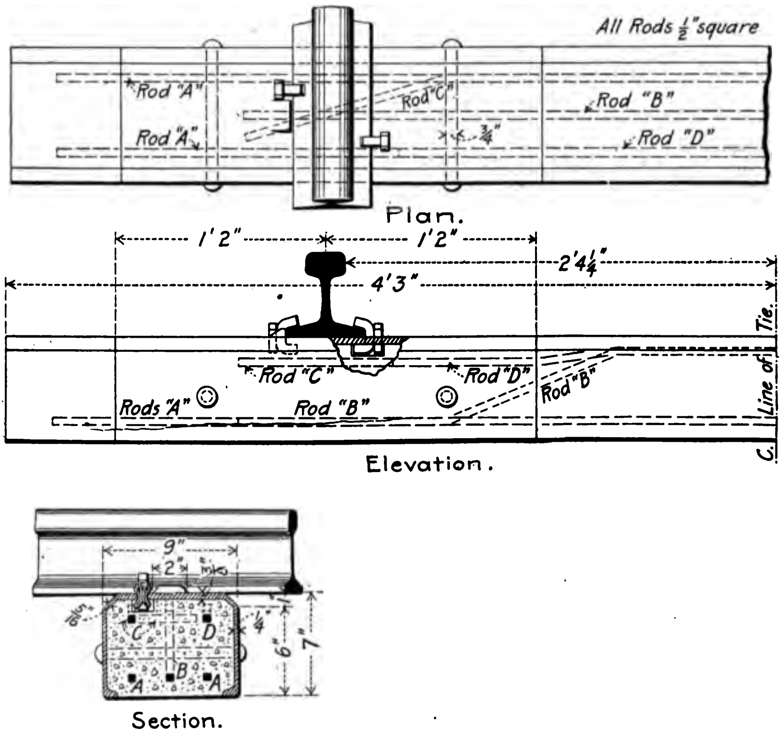

FIG. 48.—Atwood Tie.

to be more and more prevalent as the old feeling that a sawed tie is not worth having is overcome. This feeling is rapidly disappearing, and will certainly vanish entirely when it is realized that with a treated tie it makes no difference whether it be sawed or hewn.

Pole ties Fig. 49 are cut from trees as large as 17 inches in diameter. Most of them are hewn, and in the hewing much of the outer portion of the tree is wasted.

In 1906, oak, the chief wood used for ties, furnished more than 44 per cent, nearly one-half of the whole number, while the Southern pines, which ranked second, contributed about one-sixth. Douglas fir and cedar, the next two, with approximately equal quantities, supplied less than one-fifteenth apiece. Chestnut, cypress, Western pine, tamarack, hemlock and redwood are all of importance, but no one of them furnished more than a small proportion.

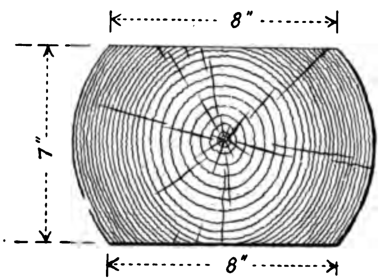

Fig. 49.—Pole Tie.

Of the total purchases of cross-ties during 1910, 139,596,000, or 94.2 per cent, were made by steam railroads, while electric railroads purchased 8,635,000, or 5.8 per cent. Largely as a logical result of the greater demand for cross-ties during 1910, the average cost per tie at point of purchase advanced to 51 cents, the same figure reached in 1907, as compared with 49 cents in 1909, and 50 cents in 1908.

Table V shows the total number of cross-ties purchased each year from 1907 to 1911, distributed according to kinds of wood arranged in the order of numbers purchased in 1911. Ten kinds of wood supply 95 per cent of all ties purchased. These are the oaks, the hard Southern pines, Douglas fir, cedar, chestnut, cypress, tamarack, hemlock, Western pine, and redwood. A

comparison of the figures for the past five years shows that no great changes which cannot be accounted for by temporary conditions have taken place in the number of ties made from the leading kinds of wood. There is no distinct trend toward the use of any one kind of wood. The more durable woods are preferred although the growing practice of treating ties with chemical preservatives is reflected in the figures for gum, maple, and beech, which were reported in very small numbers a few years ago. The various kinds of oak are drawn upon as a class far more than any other kind of wood, 44 per cent of all ties purchased in 1911 being oak. Oak ranks high in durability and hardness, and further is very widely available. Next to oak, Southern-pine ties are purchased in the largest numbers, the oaks and Southern pines together furnishing 83,773,000 ties out of the total of 135,053,000.

TABLE V

CROSS TIES PURCHASED, BY KINDS OF WOOD: 1907 TO 1911

(Bureau of the Census)

Kind of Wood.	1911	1910	1909	1908	1907
All kinds	135,053,000	148,231,000	123,751,000	112,466,000	153,703,000
Oak	59,508,000	68,382,000	57,132,000	48,110,000	61,757,000
Southern pine	24,265,000	26,264,000	21,385,000	21,530,000	34,215,000
Douglas fir	11,253,000	11,629,000	9,067,000	7,988 000	14,525,000
Cedar	8,015,000	7,305,000	6,777,000	8,172,000	8,954,000
Chestnut	7,542,000	7,760,000	6,629,000	8,074,000	7,851,000
Cypress	5,857,000	5,396,000	4,589,000	3,457,000	6,780,000
Tamarack	4,138,000	5,163,000	3,311,000	4,025,000	4,562,000
Hemlock	3,686,000	3,468,000	2,642,000	3,120,000	2,367,000
Western pine	2,696,000	4,612,000	6,797,000	3,093,000	5,019,000
Redwood	1,820,000	2,165,000	2,088,000	871,000	2,032,000
Gum	1,293,000	1,621,000	378,000	262,000	15,000
Maple	1,189,000	773,000	158,000	151,000	....
Beech	1,109,000	798,000	195,000	192,000	52,000
All other	2,682,000	2,895,000	2,603,000	3,421,000	5,574,000

29. Wood Ties. Specifications.—The following clauses taken from the New York Central Lines specifications illustrate the requirements for manufacture, size and kinds of woods accepted.

Specifications for Cross Ties

All ties shall be made from sound live timber, of the kind or kinds specified and shall be straight and free from soft or decayed knots, wind shakes, worm holes, checks or splits and other imperfections, which impair the usefulness of the tie.

Ties may be manufactured out of the full size log by sawing or hewing parallel slabs from it to give the required thickness making pole ties; or by sawing or splitting sticks of the requisite size out of larger logs. If they are split out the top and bottom faces must be dressed parallel and smooth afterwards in the same manner as pole ties.

All ties must be made of approximately straight grain timber; all ties except cedar must be entirely clear of bark before delivery; all cutting, sawing, hewing, splitting and barking must be done thoroughly and in a workmanlike manner.

The different sizes are divided into classes from A to F, as follows:

Class A Ties, $7'' \times 9'' \times 8\frac{1}{2}'$ No. 1.	Class B Ties, $7'' \times 9'' \times 8\frac{1}{2}'$ No. 2.
Class C Ties, $7'' \times 8'' \times 8\frac{1}{2}'$ No. 1.	Class D Ties, $7'' \times 8'' \times 8\frac{1}{2}'$ No. 2.
Class E Ties, $6'' \times 8'' \times 8'$ No. 1.	Class F Ties, $6'' \times 8'' \times 8'$ No. 2.

Class C and D ties may be considered as standard sizes and the specifications for these are given below.

Class C Ties, $7'' \times 8'' \times 8\frac{1}{2}'$.—All ties of this class whether sawed, split or pole ties, shall not be less than 8″ wide through the body for the entire length of the tie, by not less than $6\frac{3}{4}''$ nor more than $7\frac{1}{4}''$ in thickness between parallel faces, which faces must be at least 7″ wide under the rail and for one foot each way from the rail bearing.

Class D Ties, $7'' \times 8'' \times 8\frac{1}{2}'$.—All ties of this class shall be similar to Class " C " ties in every respect, except that the parallel faces must be at least 6″ wide under the rail and for one foot each way from the rail bearing.

The following timbers are mentioned in the Specifications and classed under a white oak group, and four groups of timbers accepted for creosoting.

The following kinds of timber will be classed with White Oak:

Post Oak	Swamp White Oak
Burr Oak	Cow Oak or Basket Oak
Chestnut Oak or Rock Oak	Overcup Oak
Chestnut Oak or Chinquapin	Black Walnut

Yellow or Black Locust

The following kinds of timber will be accepted for creosoting:

GROUP NO. 1

Red Oak	
Pin Oak or Swamp Spanish Oak	Scarlet Oak
Black Oak or Yellow Oak	Shingle Oak or Laurel Oak
Spanish Oak	Willow Oak

Honey Locust

GROUP NO. 2

Beech	Sweet, Red or Black Birch

GROUP NO. 3

Sugar Maple or Rock Maple	Mockernut Hickory
White Ash	Pignut Hickory
Bitternut or Swamp Hickory	Hackberry or Sugarberry
Shellbark Hickory	Pecan Hickory

GROUP NO. 4

Yellow Birch or Gray Birch	Cork Elm, Rock Elm or Hickory Elm
Slippery Elm or Red Elm	

From time to time timbers which have proven undesirable for the purpose are eliminated from the different groups, as recently black or wild cherry, red mulberry and sassafras have been taken out of the white oak group, water oak from Group No. 1, and soft maple from group No. 4. Beech, ash, and hickory are not taken during the summer and their manufacture and shipment are confined to the period between October 1st and April 1st.

The specifications for bridge ties of the American Railway Engineering Association are as follows:*

SPECIFICATIONS FOR SOUTHERN YELLOW PINE BRIDGE TIES

Ties shall show one side all heart; the other side and two edges shall show not less than seventy-five (75) per cent heart, measured across the surface anywhere in the length of the piece; shall be free from large knots or other defects that will materially injure its strength; and where surfaced the remaining rough face shall show all heart.

* Manual, 1911, pp. 142, 144, 150.

Specifications for Douglas Fir and Western Hemlock Bridge Ties

Ties shall show one side and one edge all heart, the other side and edge shall show not less than eighty-five (85) per cent heart, measured across the surface anywhere in the length of the piece.

Specifications for Workmanship for Bridge Ties

Ties shall be framed to a uniform thickness over bearings, and shall be placed with the rough side upward. They shall be spaced regularly, cut to an even length and line, as called for on the plans.

Switch ties are generally 7 in. by 9 in.; under railroad crossing frogs the ties may be increased in size, and sometimes 8 in. by 10 in. timbers are used.

In arranging the ties for a crossing they should be at right angles to a line midway between the center lines of the two tracks, unless the traffic on the tracks is very unequal, in which case they may be placed at right angles to the center line of the track having the heaviest traffic.

Specifications for switch ties are largely a matter of local arrangement. Those given below are a good example, and in many cases any variation from these will be mainly a matter of classification.

Specifications for Switch-Ties

Kinds of Wood

White Oaks, Red Oaks, Black Locust, Black Walnut, Wild Cherries, Beech, Birches, Maples, and Longleaved Pines are the approved woods for switch-ties. Other species of wood will not be accepted unless specially ordered.

Quality and Manufacture

All ties must be free from bark and from large, loose, or decayed knots, splits, shakes, rot, or any other defect that may impair the strength or durability of them for switch-tie use; be straight; be well manufactured; be sawed on four sides; be sawed off square at the ends; be out of wind; and have opposite sides parallel.

Longleaved Pine ties must be sawed with the heart in center or nearly so, and must not have more than two (2) inches of sapwood at the rail-bearing points on each face.

Classes and Grades of Ties

Class A. For Use without Preservative Treatment.

Species of Wood		
	White oaks	Locally known as white oak, chestnut or rock oak, post oak, burr or mossycup oak, swamp white oak.
	Black locust	Locally known as black locust or yellow locust.
	Black walnut	Locally known as black walnut.
	Wild cherries	Locally known as bird or wild red cherry, black cherry.
	Longleaved pines	Locally known as longleaf, longstraw, hard, heart, Georgia, or Florida pine slash or Cuban pine.

Class B. For Use Only after Preservative Treatment.

Species of Wood		
	Red oaks	Locally known as red oak, black oak, Spanish oak, scarlet oak, pin oak, shingle or laurel oak.
	Beech	Locally known as white beech. Red beech will not be accepted.
	Birches	Locally known as river or red birch, yellow or gray birch, sweet, black, or cherry birch.
	Maples	Locally known as sugar or hard maple, silver, soft, or white maple, red, soft, or swamp maple.

Sets of switch-ties may be furnished in any combination of Class A hardwoods. Longleaf pine must always be furnished by itself. In Class B woods a set may be composed of only one kind for the red oaks, but in cases of beech, birch and maple these woods may be combined to make a set.

Fig. 50 shows the typical plan of a No. 11 turnout recommended by the American Railway Engineering Association.

Fig. 51 shows the method of piling ties standard on the Buffalo, Rochester and Pittsburgh Railway. The piles of creosoted ties should be kept at least 10 ft. apart and all grass, weeds and other inflammable material should be kept at least 4 ft. from piles. During the summer months a layer of dirt should be kept on each pile to prevent rapid drying out, and the possibility of fire starting in the ties.

30. Wood Ties. Available Woods.—While oak is generally regarded as the best tie wood, this timber has been mostly all cut off from the regions traversed by the important roads and it is necessary to turn to more or less inaccessible territory to obtain oak ties at the present time. There are still large forests of oak, as those in the Ozark Mountains and along the Tennessee and Cumberland Rivers, but the distance the ties have to be transported adds considerably to their cost and other woods have been employed to take its place.

Probably the most important of these, in the case of the Eastern and Southern roads, are the Southern pines. The long-leaf pine is a durable and strong wood, but the short-leaf pine is softer and more liable to decay. There is apparently no botanical distinction between the long-leaf and short-leaf, but the difference in the trees is due to the character of their growth. The long-leaf is found on the uplands where the growth is slow, and the short-leaf in the lowlands where the trees have a more rapid growth. While there is a large amount of Southern pine, there does not seem to be much effort made to conserve it for a permanent supply.

A considerable amount of Northern white cedar is to be found,

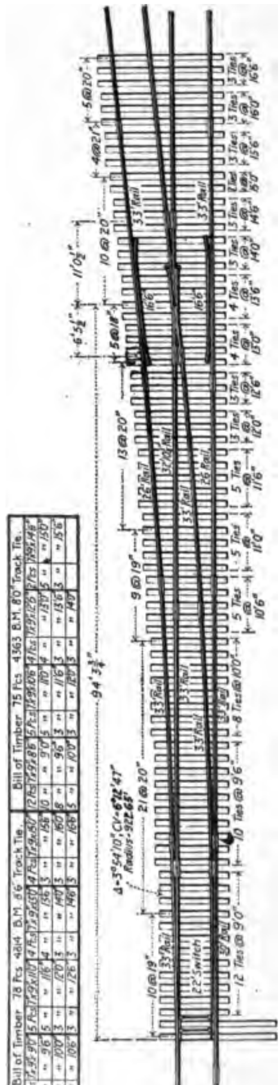

Fig. 50.—Ties for No. 11 Turnout. (Am. Ry. Eng. Assn.)

but while this timber resists decay it is a very soft wood. Chestnut has been used for tie material, although somewhat brittle and liable to split. It is doubtful, however, if it is available in very large quantities, and recently the stands of this timber have been subject to attacks from worms.

Douglas fir, western yellow pine and red wood are plentiful in the West; but the demand for these woods for other purposes and their distances from most of the roads prevent their general use.

Gum is not a very desirable wood. Ties made from this timber should be looked upon with suspicion, as they are very

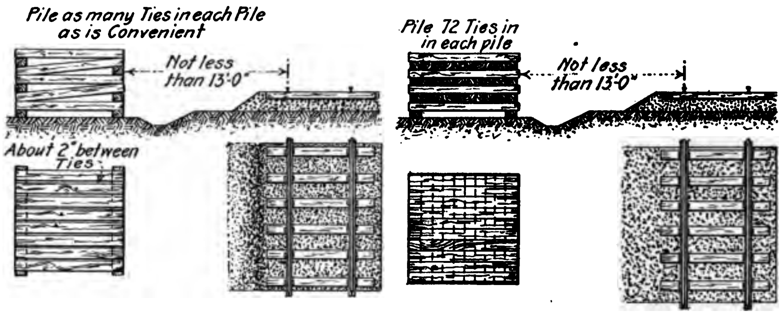

Fig. 51.—Piling Ties. (Am. Ry. Eng. Assn.)

hard to get in good condition. These ties frequently show destructive growths in the interior of the tie where the outside presents the appearance of perfectly sound timber.

While the red gum has been used quite extensively for ties by some of the roads in the Southwest in the untreated state, it must be borne in mind that such ties are composed entirely of heartwood, whereas the general run of gum ties received in the North have considerable sap and are subject to deterioration in transit. If red gum ties could be gotten to the plant in sap-green condition, much of the objection raised against this timber would be overcome. Several of the roads in the Mississippi Valley that at one time refused ties made from this

wood, now receive them by specifying that they must be delivered not later than thirty days after cutting.

There are large supplies of red gum in Arkansas, and in the opinion of some engineers this wood should receive more consideration as a tie timber by the Northern roads than is at present given to it. The prejudice against this wood has with little doubt grown out of the lack of care given to the cutting and shipping of the ties rather than to the quality of the wood itself.

Hickory and other woods of high economic value should at first sight apparently be excluded from a conservative standpoint. However, owing to the small number of ties made from these timbers, and the fact that they generally will be furnished only where there exist a few isolated trees in a stand of other timber, they can safely be accepted without detriment to other interests outside of the tie industry, and at the same time resulting in some advantage to the railroads. Sycamore is not desirable for ties on account of the brittleness of this wood in service. It is also liable to deterioration during seasoning.

Considerable difficulty has been experienced with the Northern beech on account of the tendency of this wood to split during the process of seasoning. It should be remembered that the Northern beech is quite different from that found in the South. Beech ties from Michigan are what is known as red beech and while the sapwood takes treatment readily it is very difficult to treat the heart. Southern or white beech ties are much less refractory and do not require as long a time or as high a pressure to get corresponding impregnation. In the Southern beech checking is generally almost entirely absent and many piles of these ties compare favorably in this respect with the piles of oak and other non-checking species.

Beech ties are cut from a single species and the difference in the wood of the Northern and Southern variety appears to be due to the more rapid growth of the latter. The use of the terms red and white beech refers to the red heartwood and the white sapwood of the same tree. In the beech ties from Michigan most of the sapwood is cut off and used for lumber, but the

beech ties from the South are more frequently pole ties with a large proportion of sapwood.

The term red gum likewise refers to the heartwood of the red gum or sweet gum (*Liquidambar*).

There are large supplies of Northern beech accessible, and, as apart from the question of checking, the timber affords an excellent tie; tests have been made to determine the best method of correcting this fault. The procedure has been to observe the effect of cutting the trees during the winter months when the sap is down, seasoning under sheds, which prevents rapid changes in temperature, and investigations of different forms of S irons and other methods of reducing the checking by mechanical means. These methods have proved quite successful in preventing the checking during seasoning.

It should be observed that the sawed beech tie is not as liable to split during seasoning as the hewed or pole tie, although some engineers prefer the pole tie on account of the greater amount of sapwood it contains, which can be treated, while the heart is very difficult to treat.

Winter-cut beech has been found best largely because of the rapid decay which takes place before reaching the treating plant when cut during the summer months.

Hard maple is used extensively for ties and with good results, but the soft maples offer comparatively little resistance to cutting under the tie plate. There is, however, a considerable supply of this timber available, and while its use in localities where it will be exposed to heavy service is not to be recommended, it affords a satisfactory tie under certain conditions. Care should be exercised, however, to guard against decay of the wood during seasoning.

Nearly all of the native woods except white oak were formerly accepted for treatment, but the lines are now being much more strictly drawn on account of the difficulty which has been found in keeping many of these woods in good condition while being seasoned.

31. Conservation of the Timber Supply.—The question of a future timber supply for wood ties is a very important one. The

railroads have met the problem in two ways: First, by a reduction of the amount consumed, which has been accomplished by the substitution in a limited way of other materials for wood, as the steel tie, but mainly by the extensive use of preservatives which by prolonging the life of the woods already in use and making available large quantities of timber unsuited for ties in its natural state has materially improved the situation, and second, by the adoption of forestry methods, having for their purpose the proper care and management of the forests still remaining and the cultivation of new tree plantations.

Tree planting by the railways has not been very successful and should only be undertaken on cut-over lands to encourage the growth of the natural forest tress. The ill success attending most of the experiments of this kind has been due largely to the fact that the plantations were composed of trees that were not suited to the location or conditions of the ground selected for their cultivation.

The question of growing tie timber is an individual problem with every road, but if such a policy is decided upon the only successful way to carry it out is to obtain large areas of mature timber and engage in forestry operations to manage the forest and cultivate the native trees on the cut-over areas.

There are large areas of prolific timber land in the South which can still be obtained at reasonable prices, and several roads hold timber lands, which they have placed under management with a view to providing a source of tie supply.

32. Tie Preservation. General.—The question of tie preservation is becoming more and more important as the demand for tie material increases and the traffic requirements become more exacting. So long as plenty of white oak ties could be secured, the necessity for tie preservation was not felt; but with the constantly increasing use of pine and other less decay-resisting woods, it has become a vital economic question. The railroad companies have met the problem by establishing treating plants in various parts of the United States and by laying experimental tracks with treated ties to determine the efficiency of the several preservatives under varying conditions.

The first attempt in this country to prevent decay by treating wood was in 1838 on the Northern Central Railroad. About a mile of track was laid with treated ties, but owing to the low first cost of the ties, which were chestnut and oak, and were delivered to the railroad at fourteen or sixteen cents apiece, this did not develop into a permanent industry.

In 1880, for the first time the United States census undertook to ascertain what remained of our timber resources; it was found that they had been very rapidly depleted. Realizing the importance of the question the American Society of Civil Engineers appointed a committee to report on the best methods of preserving wood, in order to lengthen its life. This committee was appointed in 1880, and after five years of work presented its report in 1885. This was followed by the movement which has culminated in the present large wood preservation industry of the country.

Fig. 52 shows the rapid increase in treated ties during recent years.

In the year 1910, 97,500,000 cu.ft. of timber was treated. Most of this material consisted of cross-ties. 63,000,000 cu.ft., which constituted about 65 per cent of the total, were treated with the creosote treatment and the remainder with zinc chloride and zinc creosote treatment in the order named.

In 1912 over twice as many ties were treated with creosote as with zinc chloride.

The cost of creosote treatment, injected 10 lbs. of creosote per cu.ft. averages about $0.40 per tie; of zinc chloride $0.17 and of the Card process with a combination of zinc chloride and creosote $0.25.*

The creosote treatment, in addition to its toxic properties, has a more or less waterproofing effect, and is itself practically insoluble in water, while zinc chloride, on the other hand, is readily soluble. This results in a leaching out of the latter preservative in moist climates and consequent early decay of the tie.

The actual preservative qualities of the treatments are, as far as is known, about the same. Tests made at the Forest

* Forest Service Bulletin, No. 118, by Howard F. Weiss.

Products Laboratory showed that ordinary coal-tar creosote had about the same toxicity as zinc chloride.

Little definite knowledge is available as to the relative life of ties treated with these preservatives, but it is generally felt that the creosote tie will resist decay for a longer period, and at the present time there is a distinct tendency toward the adoption of this process especially as applied to the woods strong enough to prevent mechanical destruction. It can be seen, however, that in the case of a tie having a short mechanical life little would

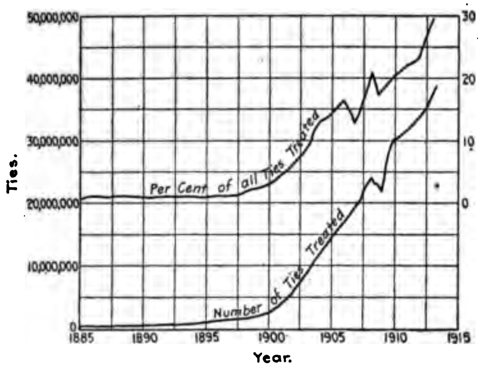

FIG. 52.—Treated Ties in the United States. (Am. Ry. Eng. Assn. Howson.)

be gained by using an expensive treatment to prevent its resistance to decay beyond its anticipated life from other causes.

33. Tie Preservation. Creosote Process.—The two important creosoting processes are the Lowry and the Rueping. The quotation given below is taken from the Lowry patent of September 18, 1906.

Herein described process of preserving wood consists of saturating wood with creosote oil under pressure while entirely submerged, then removing all free oil and immediately subjecting the wood to the action of a vacuum to withdraw most of the oil from the pores and cells therein.

The following procedure is used at the Toledo plant of the New York Central Lines, which is typical of other plants using this process: The ties are thoroughly seasoned, then placed in a cylinder and the cylinder closed. Oil is then introduced into the cylinder to completely fill it. The oil is at a temperature of 180° F., which temperature is kept constant by means of steam coils. Pressure is then put on the contents of the cylinder which varies according to the timber being treated. It is usually between 150 and 175 lbs. per square inch. This pressure is maintained until the best practical impregnation of the timber has been procured. The practice for the timbers given in the New York Central Lines specifications (Article 29) would be to continue this pressure for about two and a half hours.

The cylinder is then drained until the surplus oil is taken out, then a quick vacuum is drawn (varying from 24 to 28 ins.) from one-half to one hour duration. The timber is then withdrawn from the cylinder.

The Rueping process consists of forcing compressed air into the pores or cells of the wood and at a higher pressure creosote oil, without relieving the air pressure. Upon relieving the combined pressure and applying a vacuum the air expands and forces out surplus oil, leaving the wood fibers impregnated. It is thus seen that the essential difference between the two processes consists in applying preliminary air pressure in the Rueping process.

Fig. 53 shows the outline of a creosoting plant with one impregnating cylinder and accessories. The retort is a horizontal cylinder 6 ft. to 9 ft. in diameter, and from 50 ft. to 150 ft. long, built of steel plate made extra heavy to resist corrosion and fitted with cast-steel doors at one or both ends. Tracks are secured to the inside of the cylinder for the tie cars shown in Fig. 54 to run on. Many plants are using electric locomotives to switch the trains to the retorts and around the tie yard.

The charging tanks are usually elevated above the impregnating cylinder. At some of the recent plants the exhaust pipe is not used and heating coils are put in the tank. The oil from the charging tank is drawn into the cylinder by grav-

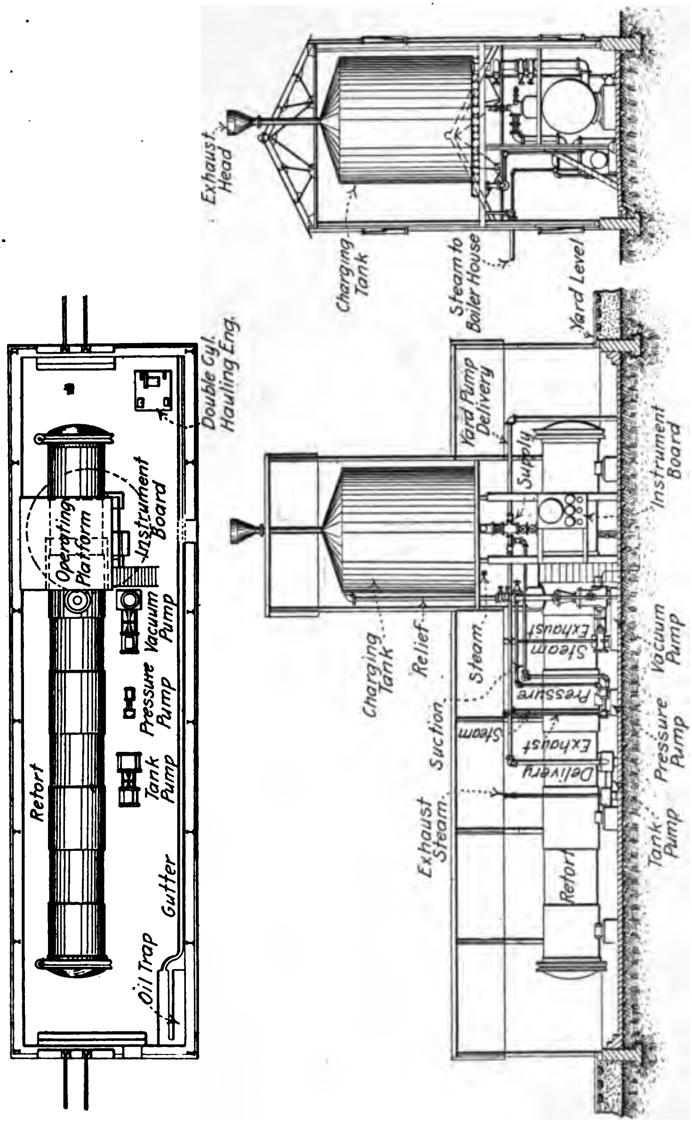

FIG. 53.—One Cylinder Creosoting Plant. (Power & Mining Mach. Co.)

ity. An emptying tank is often furnished to facilitate discharging the cylinders rapidly, and the oil from the emptying tank is then pumped back into the charging tanks.

Referring again to the tie specifications of the New York Central Lines (Article 29), the diagrams A, B, C, and D, Fig. 55, illustrate tests showing the rate of absorption of typical timbers selected from the different groups. It will be noted from an

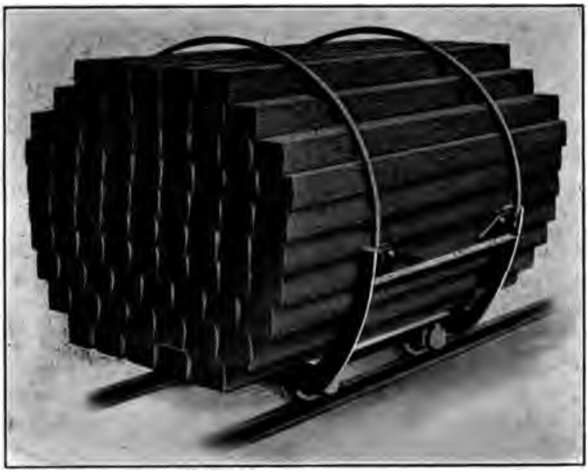

Fig. 54.—Railroad Tie Car. (Power & Mining Mach. Co.)

examination of these figures that each group possesses quite distinctive features, although in some cases groups two and three take nearly similar treatment.

In the process of seasoning, the timbers group themselves much more rapidly than by absorption. Under average conditions the following time should be allowed for seasoning:

Group 1	10 to 14 months
Groups 2 and 3	4 to 6 months
Group 4	4 to 5 months

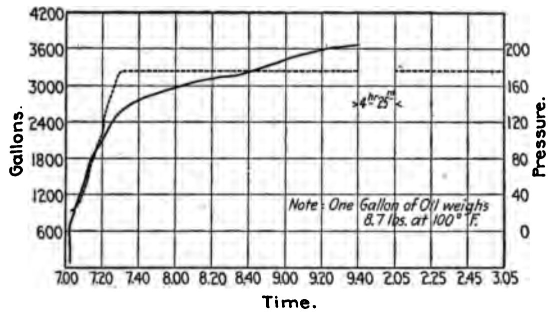

Fig. A.
Ch. No. 588, 1030 Red Oak Ties, 6"x8"x8'.

Net 3.91 Gals. per Tie.
Gross 4.14 " " "
Group No. 1 Toledo.

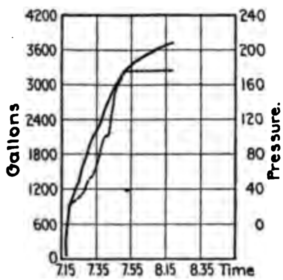

Fig. B.
Ch. No. 592, 979, Beech Ties, 6"x8"x8'

Net 2.50 Gals. per Tie.
Gross 3.71 " " "
Group No. 2 Toledo.

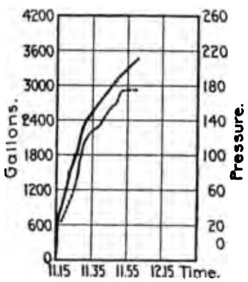

Fig. C.
Ch. No. 594, 953, Ash, Hick & H. Maple 6"x8"x8'

Net 2.50 Gals. per Tie.
Gross 3.56 " " ".
Group No. 3 Toledo.

Absorption Curve ——
Pressure " -----

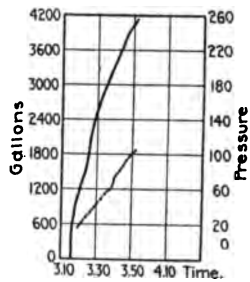

Fig. D.
Ch. No. 633, 930, S. Maple Ties, 6"x8"x8'

Net 2.58 Gals. per Tie.
Gross 4.44 " " ".
Group No. 4 Toledo.

FIG. 55.—Absorption of Different Tie Timbers.

As grouping by seasoning necessitates treating by the same groups, unless rehandling is resorted to at the plant, it does not seem desirable to use a grouping entirely on this basis, although it should be borne in mind in determining the final arrangement of the timbers.

34. Tie Preservation. Zinc Chloride Process.—This process, frequently called "Burnettizing," was invented in 1838 by Sir William Burnett of the English Navy. . The invention consisted in submitting the wood to the action of chloride of zinc. At first the impregnation was accomplished by immersion in open tanks, but later, in 1847, the timbers were placed in an air-tight tank which was capable of withstanding a pressure of 140 lbs. per square inch. As at present practiced the procedure is similar to that followed in the Lowry process, except that a solution of zinc chloride takes the place of the creosote.

The process was used quite early in Germany, as shown by the following quotation from the Stuttgart Technical Convention of 1887.*

As the experience of these railroads that have from twenty-five to twenty-six years impregnated their sleepers with chloride of zinc, under pressure, after steaming and abstracting the saps, has been very satisfactory, and as this system costs one-third or less, compared with impregnation with creosote oil or corrosive sublimate, many railroads have adopted the chloride of zinc process.

The Atchison, Topeka and Santa Fe Ry., in 1885, treated ties with chloride of zinc at Las Vegas, N. M. In treating these ties glue and tannin were added to the chloride of zinc solution with the idea of preventing the leaching out of the soluble chloride salts.

35. Strength of.—The United States Forest Service under the direction of Dr. Hatt carried out an elaborate series of tests upon the strength of treated and untreated pine ties.

The results of these tests form a body of evidence from which the following general conclusions may be drawn:

* Some Facts about Treated Railroad Ties, W. F. Goltra, 1912, Cleveland, p. 59.

1. A high degree of steaming is injurious to wood in strength and spike-holding power. The degree of steaming at which pronounced harm results will depend upon the quality of the wood and its degree of seasoning, and upon the pressure (temperature) of steam and the duration of its application. For loblolly pine the limit of safety is 30 lbs. for 4 hours, or 20 lbs. for 6 hours.

2. The presence of zinc chloride will not weaken wood under static loading, although the indications are that the wood becomes brittle under impact when treated with solutions above 3.5 per cent concentration.

3. A light treatment with creosote will not weaken wood of itself. Since, apparently, it is present only in the openings of the cells, and does not get into the cell walls, its action can only be to retard the seasoning of the wood.

The Committee on Wood Preservation of the American Railway Engineering Association in its report at the 1910 Convention of the Association presented the following conclusions, based on the best data available at the time on the strength of treated timber:

(*a*) High steaming will diminish the strength rapidly.

(*b*) Treating with strong solution of zinc chloride will render the timber brittle, perhaps because of free acid in the solution.

(*c*) Creosote is inert.

(*d*) Seasoned timber treated with light doses of creosote is as strong as the original timber.

The great variation in strength which is noticeable in timber of the same species makes it necessary to accept with caution the result of a limited number of tests representing the average of the species. One of the most troublesome factors influencing the strength of wood is the amount of moisture in it.

The Forest Service has found that a comparison of the results of tests on seasoned material with those from tests on green material shows that, without exception, the strength of small 2 by 2 in. specimens is increased by lowering the moisture content, but that increase in strength of other sizes is much more erratic. Some specimens, in fact, show an apparent loss in strength due to seasoning. In the light of these facts it is not

safe to base working stresses on results secured from any but green material.

The woods offering the greatest resistance to wear at the rail bearing are the oaks, beech, locust, hard maple and hickory. Next to these may be classed long-leaf pine, elm, hemlock and Douglas fir. Loblolly pine, short-leaf pine, soft maple, catalpa, Norway pine and cedar have little strength to resist crushing and their use should be avoided for main-line tracks under heavy traffic.

To determine the bending stress caused by the wheel load it is necessary to look upon the tie as a continuous beam loaded at the rail bearings and resting on yielding supports. In examining this stress the action of the ballast under the tie presents the greatest difficulty.

M. Coüard found that the vertical displacements of cross-ties hardly reach three millimeters ($\frac{1}{8}$ in.) and that they are not proportional to the weights supported. He has concluded from his experiments that

> the cross-ties fixed to the rail remain, at certain points, suspended above the ballast, and that right at the rail there is formed under even the best tamped cross-ties some depressions of ballast on the edges of which the cross-tie is supported; that under the passage of a wheel even lightly loaded the cross-ties come in contact with the ballast and deflect to the depth of the depressions.

Very careful experiments have been made by M. Cuënot on the relative action of the tie and the ballast, from which he drew the following conclusions:*

> That long ties, 8 feet 6 inches to 7 feet 6 inches, take, under the load, the form of a basin with the bottom slightly raised in the corner.
>
> That short ties, 7 feet to 6 feet 6 inches, are deformed according to a curve, convex or otherwise, and inclined toward the extremity.
>
> That symmetrical tamping raised the curve towards the center a very feeble lack of symmetry reacts very clearly in this direction.

* Deformations of Railroad Tracks, G. Cuënot, The Railroad Gazette, 1907, New York. Translation by W. C. Cushing.

The permanent sinking of the ballast is variable according to the case, but the elastic sinking, the only one there is reason to consider, is, so to speak, constant, whatever be the length and type of the cross-tie adopted. The deformation is slowly produced and augments with time.

The bending stress in the tie is of secondary importance to that produced by compression of the fibers at the rail bearing. A study of the elastic curve the tie takes under load is chiefly of interest in determining the proper tamping of the ballast so as to reduce the permanent movement of the ballast bed under the tie and lengthen the period between successive tampings of the track. (See Fig. 113.)

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CHAPTER VI

RAILS

36. Sections, Early.—The first Bessemer steel rails made in America were rolled at the North Chicago Rolling Mill on the 24th of May, 1865, from hammered blooms made at the Wyandotte Rolling Mill from ingots of steel made at experimental steel works at Wyandotte, Mich. The experimental steel works at Wyandotte were erected in 1864, and were the first works started in this country for conducting the pneumatic or Bessemer process. The rolls upon which the blooms were rolled at the North Chicago Rolling Mill were those which had been in use for rolling iron rails, and, though the reduction was much too rapid for steel, the rails came out sound and well shaped. The first steel rails rolled in the United States upon order, in the way of regular business, were rolled by the Cambria Iron Company at Johnstown, Pa., in August, 1867,* from ingots made at the works of the Pennsylvania Steel Company, at Harrisburg, Pa. Rails were rolled by the Spuyten Duyvil Rolling Mill Company, at Spuyten Duyvil, N. Y., early in September of that year, from ingots made at the Bessemer Steel Works, at Troy, N. Y., then owned by Messrs. Winslow & Griswold, but these were on experimental orders, and not regular ones from any railway company.†

The early steel rails were rolled in mills which had been designed for iron rails. The sewere generally pear-headed in

* See paper on the Development of the American Rail and Track by J. Elfreth Watkins, Trans. Am. Soc. of Civil Engrs., April, 1890, Vol. XXII, p. 228.

† Private communication from Mr. Robt. W. Hunt.

order to prevent the side of the head from breaking down, and were therefore not adapted to fishing. The connections at the joints were very unsatisfactory, the design preventing the fish plate, or joint, from supporting the head.*

If the joint could bear against horizontal surfaces it would not be forced out laterally by the loads, but the rail could not be properly filled by rolling and the play would rapidly increase and could not be taken up. Mr. Chanute, when he was Chief Engineer of the Erie Railway in the early seventies, experimented to determine the correct angle of the under side of the head to hold the joint, and found that with an angle above 15 degrees the joint was loosened by stretching of the bolts. This relieved the pressure and friction of the joint against the nuts and allowed them to turn. He therefore adopted the angle of 15 degrees under the head, and to avoid unnecessary metal in the flange, he made its angle 12 degrees.

By referring to Fig. 56 the pear shape of the old iron rails can be readily seen. These were followed by rails where the section was more adapted to fishing and having a better distribution of the metal to afford a stiffer rail.

The adoption of an improved section was, however, very slow, and as late as 1881, 119 patterns of steel rails of 27 different weights per yard were regularly manufactured, and 180 older patterns were still in use, making a total of nearly 300 different patterns. This great variety of sections in use required the mills to keep a large number of different rolls in stock, and finally to standardize the design of the rail, the American Society of Civil Engineers presented a section in 1893. (Fig. 57.) The rails of this section met with favor and were adopted by many railroads, so that in a few years about two-thirds of the output of the rail mills conformed to this design.

These sections proved very satisfactory for the light-weight rails then in use. The 80-lb. rail was regarded as the heaviest

* The fish plate joint was composed of two straps of iron bolted to the rail. In the English rails two keys of iron were driven between the chairs and the rail and were called "fishes." The term evidently being derived from that used by sailors in "fishing" a joint.

likely to be extensively used. This was standard on the New York Central, the Delaware and Hudson and the Michigan Central. Only one road had at that time heavier rails; this was the Philadelphia and Reading with a few 90-lb. rails.

As the heavier sections in this series came into use less satisfactory results were obtained and considerable criticism was directed against the design.

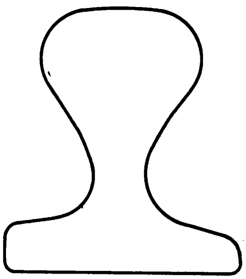


FIG. 56.—Pear Headed Rail, Buffalo, Corning & N. Y. R.R., 1857.

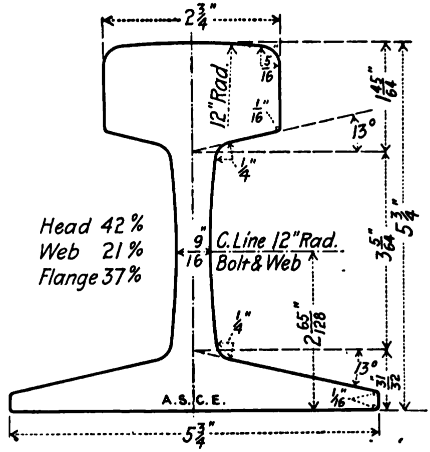


FIG. 57.—A. S. C. E. Rail Section, 100 Lbs. per Yd.

It is generally found in rolling heavier sections of any shape that modifications have to be made in the design from that used in the lighter sections. This is especially true of rails on account of their thin flanges, which at the last stage of the rolling are considerably cooler than the other parts of the rail.

37. Sections, Present.—Realizing the importance of this question, the American Railway Association appointed in 1907 a special committee on Standard Rail and Wheel Sections. This committee, through a sub-committee on which the manufacturers were represented, devoted a large amount of time and attention

to the matter of sections and specifications for steel rails and presented a preliminary report to the Association, October 1, 1907.

Accompanying the report of the committee were two series of proposed standard rail sections: Series "A," designed to meet the requirements of those who advocate a rail with thin head and a high moment of inertia, and series "B," to meet the requirements of those who think there should be a narrow, deep head, with the moment of inertia a secondary matter.

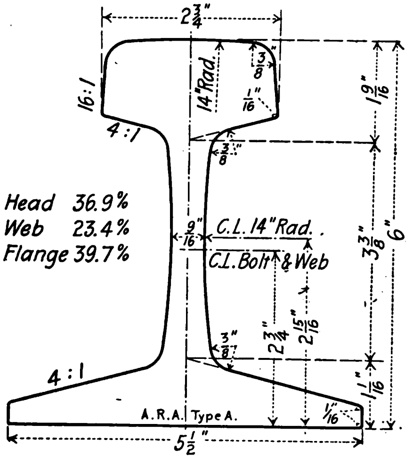


Fig 58.—A. R. A. Type A Rail Section, 100 Lbs. per Yd.

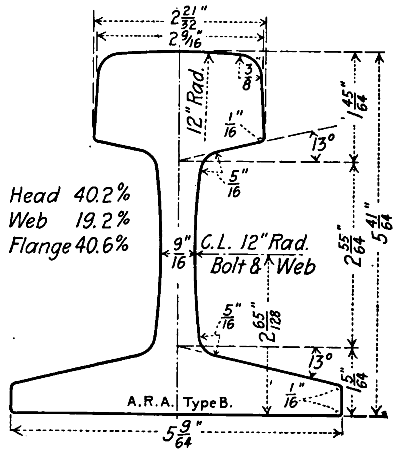


Fig. 59.—A. R. A. Type B Rail Section, 100 Lbs. per Yd.

These sections are shown in Figs. 58 and 59. The one known as series "A" has a shallower head and greater height than series "B." In this section the importance of the rail as a girder is borne in mind. Those who oppose this section fear that the shallow head is an element of weakness and prefer, as shown in the series "B" section, a rail with a heavier head as better adapted to roads having heavy wheel loads and dense traffic.

The American Railway Association Committee, in its report of October 1, 1907, submitted a statement of cardinal principles

which should govern the design of a series of rail sections, as follows:

(*a*) There should be such a distribution of metal between the head and the base as to insure the best control of temperature in the manufacture of the rail.

(*b*) The percentage of metal in the base of the rail should preferably be equal to or slightly greater than that in the head, and the extremities of the flanges should be sufficiently thick to permit the entire section to be rolled at low temperatures. The internal stresses and the extent of cold straightening will be reduced by this means to a minimum, and at the same time the texture of the section will be made approximately homogeneous.

(*c*) The sections should be so proportioned as to possess as great an amount of stiffness and strength as may be consistent with securing the best conditions of manufacture and the best service.

(*d*) The following limitations as to dimension details of the sections are considered advisable for the various weights per yard:

I. The width of base to be ½ inch less than the height.

II. The fishing angles to be not less than 13 degrees and not greater than 15 degrees.

III. The thickness of the base to be greater than in the existing sections of corresponding weight.

IV. The thickness of the web to be no less than in the existing A. S. C. E. sections of corresponding weight.

V. A fixed percentage of distribution of metal in head, web, and base for the entire series of sections need not be adhered to, but each section in a series can be considered by itself.

VI. The radii of the under corner of head and top and bottom corners of base to be as small as practicable with the colder conditions of rolling.

VII. The radii of the fillets connecting the web with head and base to be as great as possible, for reinforcing purposes, consistent with securing the necessary area for bearing surface under the head for the top of the splice bar.

VIII. The sides of the head should be vertical, or nearly so.

IX. The radii of the top corners of the head should not be less than ⅜ inch so long as the wheels continue under the present standard of the Master Car Builders' Association.

The principles (*a*), (*b*) and (*c*) above enumerated, appear to

cover the proper design of T-rail sections. The (*d*) limitations as to dimension details should be approached tentatively rather than regarded as a cardinal principle.

The sections " A " and " B " were proposed as recommended practice by the American Railway Association, and referred to the American Railway Engineering Association to study and accumulate data and make a report after the sections have been sufficiently tried in service to enable an opinion to be formed as to their respective merits.

Since October, 1907, a large tonnage has been rolled of rails substantially in accordance with the new sections, both series " A " and " B." It has been demonstrated that these sections can be finished in the mill at a lower temperature than the A.S.C.E. sections,* and therefore a finer grained and better wearing rail should be secured with the new section. However, great care must be exercised at the mills to see that rails are actually rolled at lower temperatures.

The 90-lb. series " A " is now used on a majority of the Western prairie roads, and the " B " section is used on the group of coal roads in Maryland and Virginia. On account of the heavier head found in the " B " section, it seems to be preferred by the crooked roads of the East, especially those in the mountains of Pennsylvania, Virginia and Maryland; while on the prairie roads, where little curvature is found, the series " A " rail with the lighter head finds more general use.

Fig. 60 shows the type of rail recommended by the Committee on Rail of the American Railway Engineering Asslciation, in 1915. The Committee offered no new designs for sections under 100 lbs., and for the 90-lb. section recommended the A.R.A " A " section for the single type standard. It will be observed that the design submitted has a high ratio of section modulus to area of section, and that the Committee has kept in mind the feature of the rail as a girder.

On June 5, 1907, a joint committee of Mechanical and Civil Engineers of the Pennsylvania system was appointed to study

* This refers to the temperature of the head; no part of the new sections is finished as cold as the thin bases of the A.S.C.E. rails.

the rail question, and on September 20 of the same year reported sections for 85-lb. and 100-lb. rails. (Fig. 61.) This section, as in series " B " of the American Railway Association, has a heavy head and low ratio of section modulus to area, the Pennsylvania evidently considering that with the character of their line the head should be strengthened as much as possible.

The New York Central is using a section designed by Dr. P. H. Dudley, quite similar to the American Railway Associa-

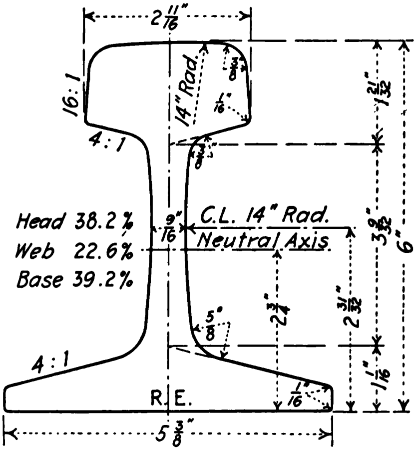


FIG. 60.—R. E. Rail Section, 100 Lbs. per Yd.

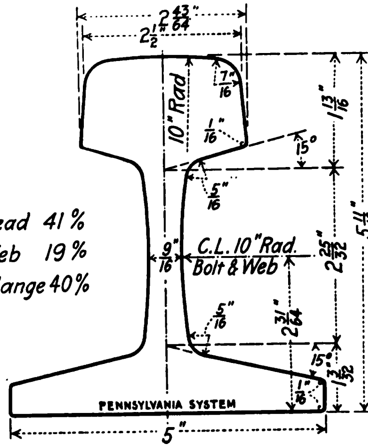


FIG. 61.—P. S. Rail Section, 100 Lbs. per Yd.

tion Series " A," but with a radius of 1 in. for the fillet between the base and the web. This section is shown in Fig. 62.

38. Sections, Foreign.—In Europe, a T-rail section is used. The Vignole rail, used extensively abroad, was invented in England in 1836 by Mr. Chas. Vignoles. In England, however, the idea seems to prevail that a T-rail track is undesirable and the bull head rail is generally used on the English railways. **Fig. 63*B*** shows the 100-lb. section of the British Standard bull head rail.

39. Height.—The 90-lb. and 100-lb. sections are now generally adopted as standard on American railroads. **Sections of**

heavier weight have not met with general favor, although there are a few exceptions, notably the 105-lb. rail standard on the New York Central, illustrated in Fig. 62, and the 135-lb. rail in use on the Central Railroad of New Jersey. One thousand tons of this latter rail were ordered in 1910 for use on sharp curves. Subsequent orders were placed in the years 1912, 1913 and 1914, bringing the total tonnage up to 6600 tons. This rail has very high carbon and one of the reasons for the road try-

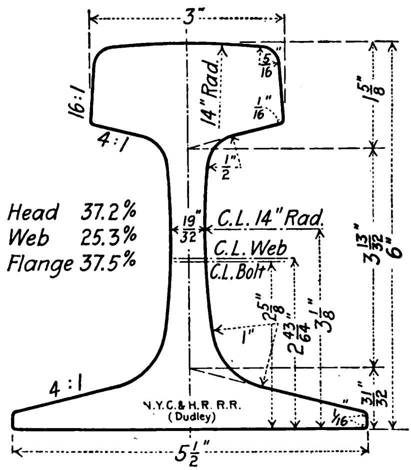


FIG. 62.—Dudley Rail Section, 105 Lbs. per Yd.

ing the heavy section was to enable a higher carbon content to be used than would be considered safe in the 90- or 100-lb. rail.

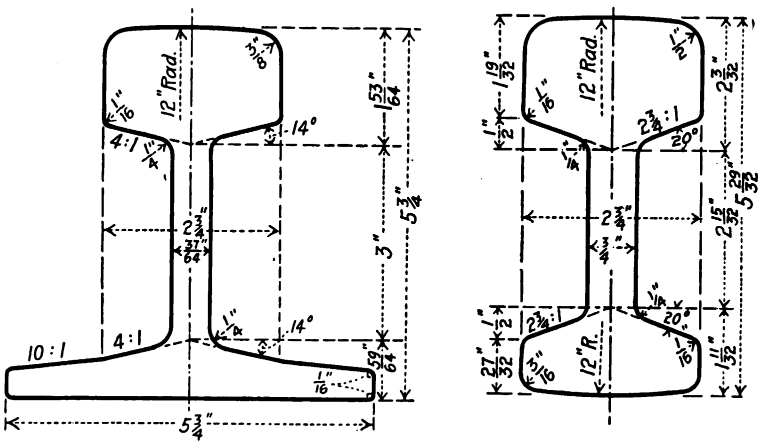
The Pennsylvania have ordered a considerable tonnage of 125-lb. rail and are gradually putting it in the track for test.

The heaviest rail contemplated in the A.S.C.E. and the A.R.A. sections was the 100-lb. The new section of the American Railway Engineering Association starts at the 100-lb. rail and gives designs for sections as heavy as 140 lbs. It does not

appear, however, to be the intention that these very heavy rails should be adopted for present use.

The principal reason in going to heavier sections has been to reduce the stresses in the track structure. It should be observed, however, that good results are not always obtained as the weight increases, owing to the difficulties met with in the manufacture of the rail.

In considering the proper design for a rail, the subject should be approached from two points of view: First, the stresses in



A. Flat Bottom "B. S." Section, No. 100, 100 Lbs. per Yd.

B. Bull Head "B. S." Section, No. 100, 100 Lbs. per Yd.

FIG. 63.—British Standard Railway Rails.

the rail itself and its ability to transmit the load so as not to overstress the track structure; and second, the effect of the design upon the details of manufacture and the character of the material of which the rail is made. It will be seen that a knowledge of the stresses in the rail will be of little advantage unless it is also known what stresses the material of the rail is capable of resisting.

40. Stresses.—In recent years much thought has been given to the manufacture of rail-steel, and investigators, it would seem, have turned their attention more to an examination of the various defects found in the process of manufacture than to the study of the duty of the rail.

Quite early the question of the intensity of pressure existing between the wheel and the rail began to receive attention, but it was not until later that the bending stresses in the rail were investigated. Purely theoretical contributions to the latter subject were made by Zimmermann in 1888. The first practical investigations of the bending stress in the rail were apparently those made by the United States Government in 1893 by measuring the strains in the rail under the static load of the locomotive wheels. These were followed by Dr. P. H. Dudley's stremmatograph experiments for measuring the effect of dynamic loads. In the time elapsed since the publication of these investigations hardly anything has been done to further elucidate this problem.

The principle of the wheel is a line contact on the running surface. In practice, on account of the compression which takes place at the bearing surface, this is never realized, but nevertheless the bearing surface is always very small. The ordinary compression modulus, determined by tests on prisms having the same bearing surface as their greatest section, has no relation to the stress which exists at the area of contact between the wheel and the rail. The material in the latter case receives support from the surrounding metal, and is therefore not wholly free to move under the high stress to which it is subjected. It should be remembered that the application of stress alone has very little effect upon the steel unless it results in strain. This has been shown in experiments in cubical compression where a block of steel has been placed under very high hydraulic pressure without producing appreciable compression.

The compression under the wheel is not entirely a case of cubical compression and can be understood from the following explanation given by Professor Johnson.

* Paper contributed by Professor Johnson to the Engineers' Club of St. Louis, December, 1892.

When a plain cylindrical column is subjected to a uniform pressure or stress over its entire cross-section, as Fig. 64*A*, it may be said to be in a condition of "free flow," since it is free to spread in all directions throughout the length of the column. In Fig. 64*B* the material is compressed uniformly over a small area, as with a die. Here there is a flowing of the metal laterally, and then vertically, finding escape around the edges of the die. This is a condition of confined or restricted flow, and evidently the elastic limit here will be much higher than with the simple column.

In Fig. 64*C*, the surface is compressed by a cylinder, the greatest distortion being at the middle of the area of contact.

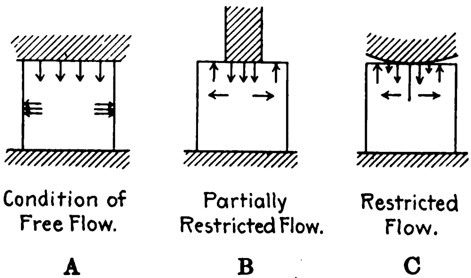


FIG. 64.—Compression Moduli. (After Johnson.)

When this metal is forced to move, or flow, it can find escape only out around the limits of the compressed area. But at these limits the metal is a very little compressed, and, hence must be moved from the center. The confined ring of metal inside the limits of external flow is now much wider, and, hence, the real resistance to flow much greater, so that this condition will be found to have a higher elastic limit stress than that shown in Fig. 64*B* and very much above the ordinary "elastic limit in compression" which is found for the free-flow condition of Fig. 64*A*.

Professor Johnson experimented * to determine the area of

* Friction Rollers (Discussion of Paper No. 722), J. B. Johnson and A. Marston, Trans. Am. Soc. of Civil Engrs., September, 1894, Vol. XXXII, pp. 270–277.

contact between locomotive and car wheels and rails. Sections of wheels were mounted in a 100,000-lb. Riehlé testing machine and short sections of rail were placed in the machine so that the wheel treads rested upon them in a normal position. They were then loaded with 5000-lbs. increments from 5000 to 60,000 lbs., the area of contact being measured after each loading. In Fig. 65 these areas are plotted with the area of contact as ordinates and the loads as abscissa.

Fig. 66 presents some of the experiments made by the Ordnance Department, U. S. Army, during the month of October,

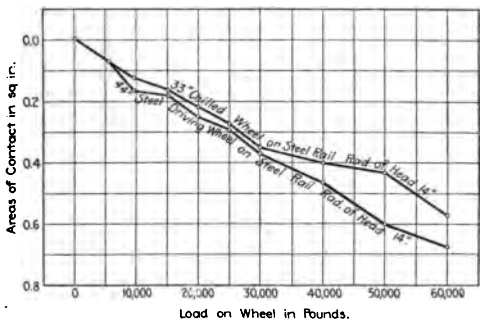


FIG. 65.—Relation between Areas of Contact and Load on Wheel. (After Johnson.)

1893, on the track of the Chicago, Burlington and Quincy Railroad, at Hawthorne, Ill.

The experiments consisted of measuring the depression of the rails under the weights of different classes of locomotives, and the fiber stresses developed in the base of the rail.

For the purpose of observing the depression of the rails, bench marks were established on a row of stakes driven alongside the rail, 31 ins. distant from it. A beam carrying a micrometer and an astronomical level bubble was used in observing the depression of the rail, first measuring the height, using points on the outer flange, when the rail was unloaded, and repeating the observations when the engine was standing on the track.

Fig. A shows the depression of one rail its entire length and the ends of contiguous rails, the locomotive occupying one position thereon as shown with reference to the rail and ties.

Fig. B shows the curve of depression under another type of locomotive. This engine had no leading truck nor tender, but had a two-wheeled trailing truck.

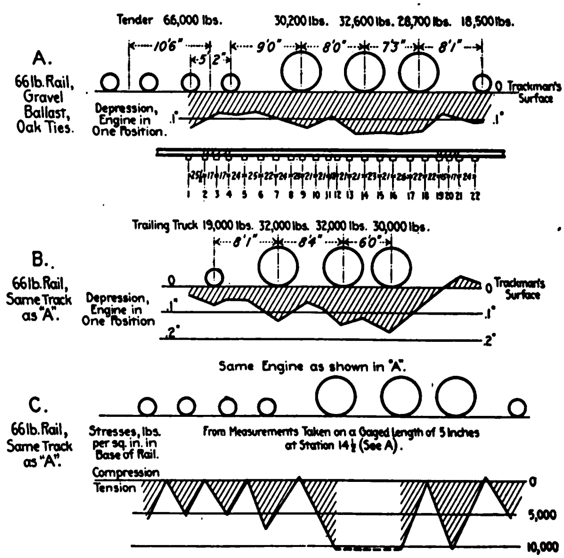


FIG. 66.—Rail Stresses, U. S. Government Tests; C. B. & Q. R. R.

In the position it occupied during the test, the greatest depression of the rail occurred under the forward drivers, the rail presenting a sharp acclivity before the engine, and beyond the joint the contiguous rail rose slightly above the normal level.

In the diagram, Fig. C, are shown the fiber stresses as measured on the base of the rail at Station 14½, midway between ties Nos. 14 and 15.

In Fig. 67 are shown the results of tests made by Dr. P. H. Dudley with the stremmatograph.* The principle of the stremmatograph is to record on a moving strip the molecular compression or elongation of the metal in a given length of the base of the rail, induced by the strains produced by each wheel of

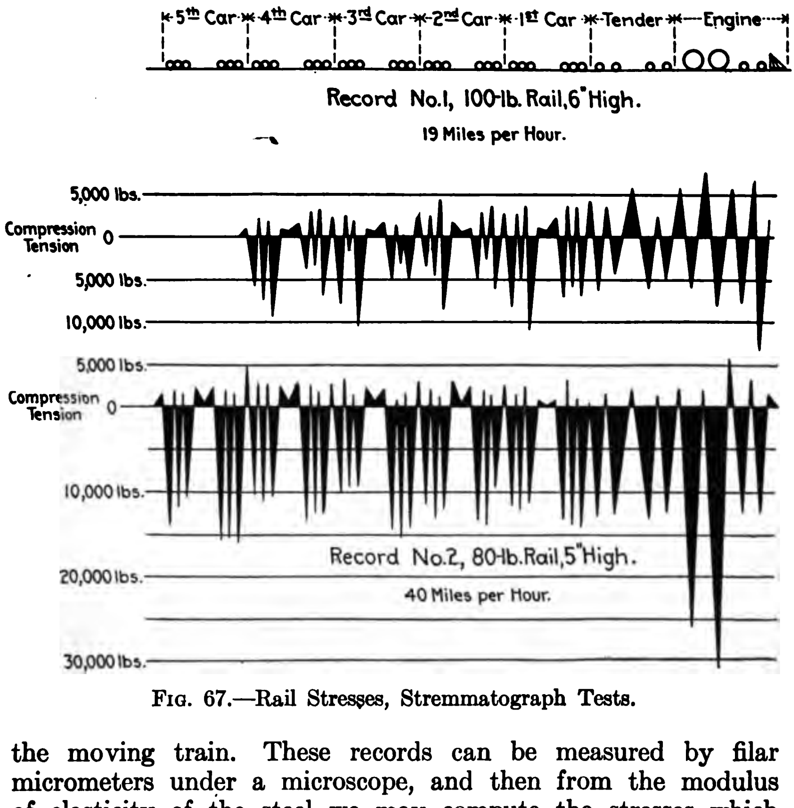


FIG. 67.—Rail Stresses, Stremmatograph Tests.

the moving train. These records can be measured by filar micrometers under a microscope, and then from the modulus of elasticity of the steel we may compute the stresses which produce the given compression or elongation per square inch of the extreme fiber in the base of the rail.

* Railroad Gazette, May 20 and October 21, 1898.

The object of the stremmatograph is to convert rails of any section and weight, of any system of permanent way construction, into testing machines in the track and show how much they are strained, due to the wheel loads and spacing of any type of locomotives and cars moving over the rails at the different speeds of service.

Record No. 1, Fig. 67, is taken on the New York Central and Hudson River Railroad tracks. The instrument was applied on the outside rail of a 3-degree curve at the Grand Central Terminal, over which nearly all of the heavy trains from the terminal pass outward; the tonnage was from 20,000 to 25,000 per day, and there was more looseness in the track than generally found out on the main line. The following are the data of the test:

Date	June 28, 1898
Weight of rail	100 lbs. per yard.
Height of rail	6 ins.
Ballast	Stone
Ties	Oak with tie plates spaced 24 ins. center to center
Speed, miles per hour	19
Temperature	90° F.
Locomotive and tender	202,000 lbs.
First car	95,000 lbs.
Second car	86,200 lbs.
Third car	82,000 lbs.
Fourth car	94,950 lbs.

Record No. 2, Fig. 67, was taken at West Albany (N. Y. C. & H. R. R.R.) September 30, 1897. The engine was drawing five Wagner palace cars at a speed of 40 miles per hour; 80-lb. rail, 5 ins. high; ties spaced 25 ins., center to center.

Dr. Dudley states that tests with his stremmatograph show that the bending moments in 80-lb. rails under wheel loads used in 1905, may be as high as 300,000 to 350,000 in.-lbs., indicating a unit fiber stress in the base of the rail of as much as 30,000 or 35,000 pounds on worn 5-in. 80-lb. sections. With 65-lb. rail, stresses were frequently found as high as 40,000 to 45,000 lbs.

41. Manufacture. The Blast Furnace.—The location of the plant is usually chosen according to the cost of assembling the materials for smelting and getting the product to the market. Other things being equal, that furnace will be most economically located which is placed near the mines. Where the ores and fuel are widely separated, the location is often determined by the facilities for marketing the iron, and the furnace is so placed that the total of all the costs of transportation and of working shall be a minimum.

The notable present tendency in the iron industry is the lower average iron content in the ores used. This tendency will undoubtedly continue in the future as the more easily accessible portions of the richer deposits are worked out. As a corollary to this is the observed tendency toward a decentralization of the iron industry, and with a decrease in the iron content of the ore used, involving a corresponding increase in cost of transportation per unit of iron, there will be an increase in the proportion of fuel which goes to the region producing the ore.

The blast furnace is shown by Fig. 68. It is a brick structure, usually circular in section and built in two parts; the upper part resting on columns, while the lower portion rests directly on the foundation. The upper portion is sheathed with boiler plates.

In the United States furnaces are worked up to 100 ft. high. The best modern practice is, however, about 90 ft. high, with a product of 400 to 500 tons per day. The following dimensions of the Gary furnaces are typical of the best practice. The blast furnaces are 88 ft. in height from the tap hole to the top of the furnace lining, and the capacity of each is 450 tons per day. Each furnace has four blast stoves. The interior diameter of the blast furnace is 15 ft. at the hearth, 21½ ft. at a height 13 to 21 ft. above the hearth, and 16 ft. at the top.

The materials for smelting are iron ores, limestone (flux) and fuel. Charcoal was first used, and the iron from this fuel was of excellent quality on account of the low ash and sulphur of the charcoal and its great porosity. It has so little strength, however, that its use in the modern high furnaces is prohibited.

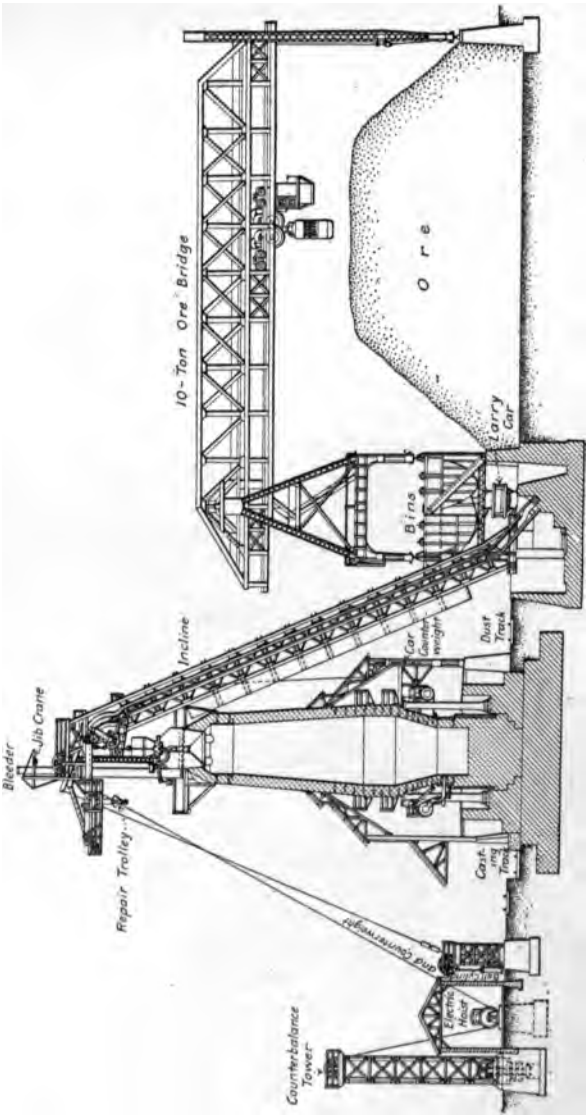


FIG. 68.—Sectional View of Hazelton Blast Furnace, No. 4.

Coke is now generally used. Anthracite as a blast-furnace fuel is inclined to decrepitate and give trouble from its fineness. Bituminous coal is not used, as it cakes and absorbs heat for distillation of volatile constituents.

At Gary,* between the stock pile and the furnace is a line of elevated storage bins arranged in two parallel rows. One row is for coke and the other for ore and limestone. Above the bins are four tracks on which travel two 60-ton electric transfer cars. The ore is loaded into the transfer cars by the buckets of the overhead ore bridges. The coke and limestone are brought up over the bins by rail and deliver their load directly by gravity.

At the bottom of the bins are spouts controlled by electrically operated gates, and below these are tracks which run the full length of the bins. Traveling on these tracks are electrically operated lorries into which the ore, coke and limestone are delivered from the bin spouts. The lorries carry the materials to what are known as the "furnace skips," of which there is a pair to each furnace. The skips run on an inclined railway which runs direct from the pit below the transfer cars to the charging platform at the top of the blast furnaces.

The operation is entirely automatic. Each trip of the skip is made in about sixty seconds, and its average load consists of about 7000 lbs. of ore or 6000 lbs. of limestone, or 3600 lbs. of coke.

42. Manufacture. Bessemer Process.—For nearly half a century the Bessemer process was the principal method used for making steel. It was introduced about the time that the wrought-iron rails were beginning to show their weakness under the increasing loads being placed upon them, and by its great capacity reduced the cost of steel so that this material could be used in place of iron for rails.

The Bessemer process consists in an agitation of molten cast iron in the presence of the oxygen contained in the atmosphere. The oxidizing atmosphere is forced up through the molten mass, which produces combustion and the removal of carbon. The metal from the blast furnace contains, let us say,

* See Scientific American, December 11, 1909.

about 3.5 per cent carbon; this carbon is nearly all burned out, reducing the cast iron from the blast furnace to the state of wrought iron, then carbon is added to the bath in sufficient quantities to change the wrought iron to steel.

Fig. 69.—Bessemer Converter in Full Blast.
(By permission of American Technical Society, Chicago, Ill.)

The blow generally requires about ten minutes. The blast furnace metal is poured into the converter, which is then placed in the position shown in Fig. 69. Compressed air is forced up

through the molten iron, increasing the heat of the metal, and the flame shown in the figure is at first red, but rapidly becomes brighter and then suddenly drops and the operator turns down the converter and shuts off the blast. Spiegeleisen or ferro-manganese is then added to recarbonize the metal.

43. Manufacture. Open-hearth Process.—The basic open-hearth process is rapidly supplanting the Bessemer process. (See Fig. 70.) This is probably due largely to the supply of low-

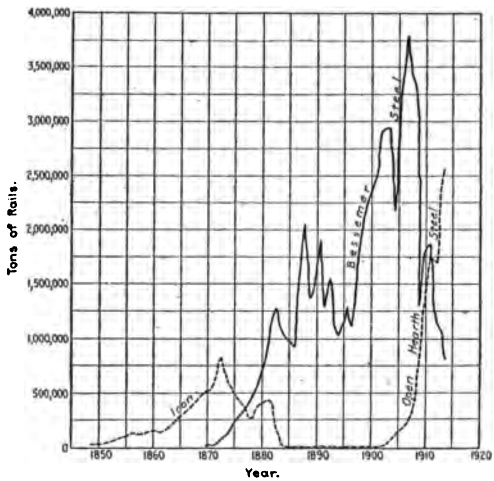


FIG. 70.—Tons of Rail Rolled, 1850–1913. (Am. Ry. Eng. Assn. Howson.)

phosphorus ores being exhausted, as otherwise, on account of the great capacity of the Bessemer process the open hearth would have little chance.

With the Lake Superior ores, which are the mainstay of pig-iron production in this country, it is difficult to keep the phosphorus content of the steel in the Bessemer process below 0.10 per cent, but when these ores are treated in the basic open-hearth furnace they produce a metal of excellent quality with phosphorus as low as 0.04 or 0.03 per cent.

The open-hearth furnace consists of a basin or hearth. Currents of gas and air are passed over the bath, oxidizing the metal. In addition to the oxidizing action of the flame, scrap steel

FIG. 71.—Teeming Ingots at Open-Hearth Furnace. (Copyright, Keystone View Co.)

is added, which reduces the percentage of carbon and silicon of the molten pig metal. The open-hearth heat requires a much longer time than a Bessemer blow, the 80-tons furnace at Gary

taking about eight or nine hours as compared to the 10 minutes blow of a Bessemer converter.

After the conversion of the steel it is poured into the casting ladle and then cast into molds. (See Fig. 71.) If slag is allowed to pass into the ingot molds with the steel, the latter is liable to be spoiled, and in consequence the steel cannot be poured from a lip into the molds, but has to be tapped or teemed from a hole in the bottom of the ladle.

The time allowed after the conversion of the steel and when it is held in the converter or casting ladle exercises considerable influence upon the finished product. The thorough mixing of the recarbonizer, and the opportunities for the impurities to separate from the metal and the gas to escape from the molten steel are of importance. Dr. P. H. Dudley requires a definite interval of time between the additions of the spiegel and the teeming of the steel.

44. Manufacture. Duplexing.—On account of the change from the Bessemer to the open-hearth process a great deal of the Bessemer capacity in the older plants was thrown out of employment, and there was naturally a desire to find a use for these converters. The duplex process, which is a combination of the Bessemer and open-hearth processes, supplies this need.

In this process the acid Bessemer converter removes the silicon together with a considerable portion of the manganese and a certain amount of the carbon. The metal is then transferred to the basic open-hearth and the remainder of the carbon is removed and the phosphorus reduced in the usual manner.

This process is especially adapted for pig which contains too large an amount of silicon for use in either the basic Bessemer or basic open-hearth.

45. Manufacture. The Ingot.—The defects of the ingot are due mainly to the following three causes:

1. A funnel-shaped cavity or pipe at the top of the ingot.
2. Dispersed cavities or blow-holes throughout the ingot.
3. Segregation of the impurities of the steel, as silicon, phosphorus, manganese, etc., from the mass of the metal and their concentration in different parts of the ingot.

The pipe is due to the contraction of the interior of the mass after the outside has set. After molten steel has been cast into an iron mold, the metal in contact with the bottom and the sides begins first to solidify, the top next becomes solid and the ingot presents the appearance shown in Fig. 72. As the steel in cooling contracts, a cavity or pipe is formed when the entire ingot becomes solid, and as the freezing of the metal takes place from the sides and bottom first, this is located in the upper part of the ingot where the metal remains fluid longest.

Blow-holes generally form in the upper half of the ingot, which is permeated by honey-combs or dispersed cavities, due to the liberation of imprisoned gases, principally hydrogen, as well as nitrogen and carbon monoxide. These gases are absorbed, dissolved, or occluded in the molten steel, but are wholly or partially evolved and collect into bubbles when the metal begins to solidify.

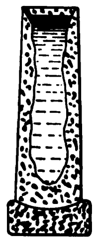


FIG. 72. Formation of Pipe in Ingot.

Steel contains different impurities, as silicides phosphides, carbides, sulphides, etc., whose freezing or solidifying points vary, and all have a lower melting-point that the metallic iron, consequently those having the lowest melting-point will tend gradually to segregate from the iron and concentrate in the hottest part of the ingot. The top and center of the ingot always contains the larger proportions of impurities.

Titanium when rightly applied in the proper amount appears to deoxidize the steel, giving a sounder ingot quite free from blow-holes, but with a large cavity or pipe.

Several methods have been tried to eliminate the pipe in the ingot, and while none can be said to have attained commercial success as applied to the manufacture of rail steel in this country, the process invented by Sir Robert Hadfield, a prominent English steel manufacturer, deserves mention. In this process after the ingot mold, which is furnished with a sand or fireclay top, is filled to the desired height with molten steel, a layer of slag about one-half an inch thick is placed upon it and on the top

of this is placed a quantity of charcoal. Then, through suitable piping, an air blast is directed in numerous jets upon the charcoal, which is burned thereby, the combustion supplying additional heat to the top of the ingot, which helps to keep the top fluid and to retard its solidification, while the lower parts are rapidly

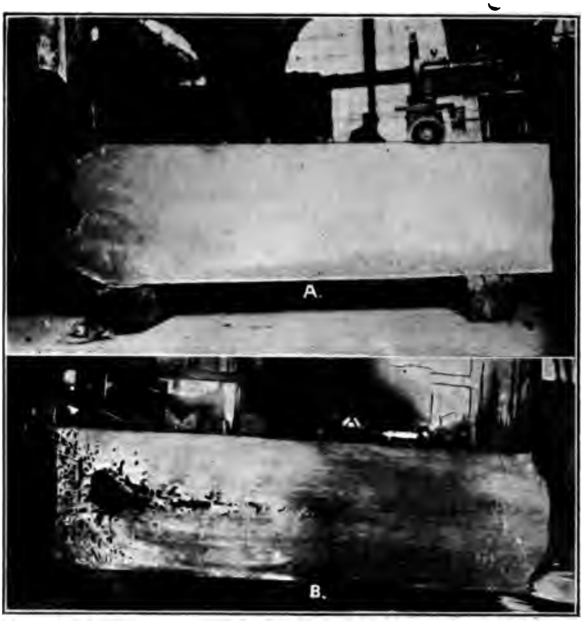


FIG. 73.—Sections of Ingots. *A*, Hadfield Ingot; *B*, Piped Ingot.

losing heat by its transfer to the mold. This ensures ingots free from unsoundness, blowholes, piping, or segregation.

Fig. 73 compares an ingot (*A*) made by the Hadfield method with an ordinary rail ingot (*B*). A sulphur print taken of one half face of the Hadfield ingot indicated very uniform distribution of the constituents in the metal and practical freedom from segregation, while, as would be expected, the ordinary

ingot, with its pronounced pipe, showed marked segregation of carbon, phosphorus and sulphur in the piped region to a depth of 25 per cent from the top of the ingot, and other regions of somewhat varying composition. The manganese showed but slight segregation anywhere.

The Pennsylvania Railroad has ordered 100 tons of ingots made by the Hadfield process for the purpose of rolling these into rails.

It may be mentioned that the discard with these ingots is remarkably small and about one-half that ordinarily required yet steel is being obtained free from piping and segregation.

46. Manufacture. Rolling.—The principal points in connection with the rolling are given below:

1. Resistance to wear is a function of fineness of grain.
2. Fineness of grain is principally a result of mechanical treatment at proper temperature.*
3. Work done on steel above 950°–1050° C. (1742° F.–1922° F.) has less effect on changing the size of grain from the normal crystallization of the ingot than when the rolling is done at a lower temperature.

Fig. 74 illustrates views taken by Mr. James E. Howard and shows the gradual reduction of the bloom to the finished rail as it passes through the successive rolls.

In 1909 a further investigation was made of the steel at different stages of the rolling by Mr. Howard at the Watertown Arsenal.† In these tests, beginning with the ingot, the structural state of the metal was examined by taking cross-sections and longitudinal sections. This method was carried through the various successive derivative shapes, and the results obtained are shown in the large number of illustrations which form the body of the report.

The greater part of the work was devoted to Bessemer rail steel, five acid Bessemer heats being made for this series of tests,

* This should not be interpreted as meaning that resistance to wear is not also a function of the chemical composition.

† Tests of Metals, etc., 1909, Vol. 1 and Vol. 2, Government Printing Office, Washington.

B. Rail from an Early Pass in Roughing Rolls. Rolled from Bloom shown in *A*.

C. Same Rail as Shown in *B* after Furtl Reduction.

A. Cross-section of 8×8-in. Bloom.

D. Finished Rail from Same Ingot as Blo and Pieces from Roughing Rolls.

FIG. 74.—Sections from Bloom to Finished Rail. (Am. Ry. Eng. Assn. Howard.

each heat furnishing six ingots about 19½ by 20½ ins. at the bottom and about 5 ft. high.

One of the most important results of the tests was to throw light on the question of the amount of work or reduction necessary in rolling to develop the full physical qualities of the steel. Mr. Wickhorst * draws the following conclusion from the tensile tests made of specimens taken at various stages from the ingot to the finished rail:

The results indicate that the metal in the walls of the ingot takes comparatively little work or reduction to impart to it what may be called its full physical properties of tensile strength and ductility. These are reached in the bloom, except at the top end. The axial metal at the bottom of the ingot also soon reaches its full physical properties, but in the upper half of the ingot it must be carried well toward the finished rail before these properties are fully developed.

Where the metal is of fairly even composition and free from sponginess, it reaches its full physical qualities of tensile strength and ductility at about ten reductions, or a reduction to one-tenth of the original cross-section of the ingot, but the interior portion of the upper part of the ingot requires twenty-five or more reductions to have its full physical qualities developed, that is, the cross-sectional area must be reduced below one twenty-fifth of its original amount.

The effect of finishing temperature is not fully agreed upon, and many rolling-mill men feel that the properties of the steel depend quite as much on the amount of reduction in the rolls as upon the finishing temperature.

The pass diagram of the rail mill at the South Works plant of the Illinois Steel Company is illustrated in Fig. 75. The Bessemer ingot is 18 ins. by 19½ ins., the heating capacity is 192 ingots (24 single-hole pits). The ingot is worked direct to rail without reheating. The blooming mill is 40-in. pitch diameter three-high, and the ingot is given 9 passes and reduced to an 8-in. by 8-in. or 8-in. by 8½-in. bloom. The number of rail lengths rolled are three and four.

* Report to Rail Committee Am. Ry. Eng. Assn. Proceedings, Vol. 13, 1912, p. 794.

The finishing mill consists of one stand 28-inch P.D. three-high first roughing rolls, one stand 28-in. P.D. two-high dummy rolls, one stand 28-in. P.D. three-high finishing rolls.

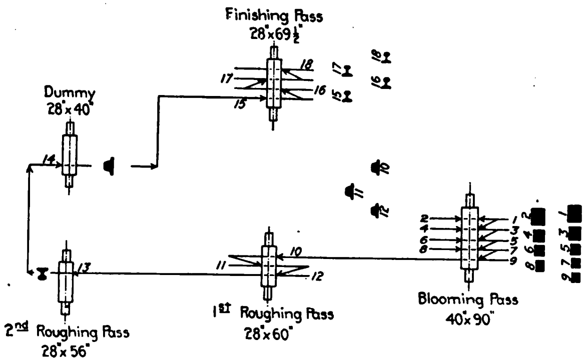


FIG. 75.—Pass Diagram, Rail Mill, Illinois Steel Company, South Works.

The number of passes from ingot to rail is as follows:

	Passes
Blooming	9
First roughing	3
Second roughing	1
Dummy	1
Finishing	4
Total	18

After being rolled and sawed to length the rails pass through the cambering machine and are given a head sweep (Fig. 76) of from 3 to 8 ins., the A.C.S.E. section requiring a greater ordinate than the A.R.A. rails. The rails then pass to the hot beds and after being allowed to cool are transferred to the gagging or cold-straightening presses. Unless the gagging is carefully done, the rail may be injured by developing injurious strains in

FIG. 76.—Head Sweep.

the base and web; this is especially true of the A.S.C.E. sections. After straightening, the rails are inspected, drilled, reinspected and loaded on cars for shipment.

47. Chemical Composition. Effect of Different Elements.— Carbon is the most important element, except iron, in steel, and the mechanical properties of iron-carbon alloys are closely connected with the relative amounts of the two elements. The tenacity and hardness of the steel increases rapidly with an addition of carbon.

Silicon in small proportions hardens the steel and stands intermediate between carbon and phosphorus in this respect. Silicon as high as 0.2 per cent in rail steel of 0.5 to 0.6 per cent carbon probably has no injurious effect.

Phosphorus hardens steel more rapidly than either carbon or silicon. It increases its rigidity but impairs its power to resist impact. Small proportions render the metal harder without materially affecting its tenacity, but makes the metal at the same time decidedly cold-short or brittle when cold.

Sulphur has little influence on the tensile strength or ductility. The real effects of sulphur, however, are seen during the rolling, a very small percentage causing a great red-shortness, or causing it to be brittle when heated at a red heat. Its presence in excess of 0.06 or a maximum of 0.08 per cent tends to cause cracks to develop during the rolling, which, while they close up and are almost imperceptible in the finished rail, nevertheless remain as flaws and may form starting-points for rupture when the rail is subjected to any sudden stress. With sulphur it is necessary to work the metal at a high heat to avoid its cracking during manipulation. The "red-short" term means that as the heat approaches the red color the tendency to crack becomes intensified.

Manganese has a general tendency to increase the tensile strength and reduce the ductility, this influence varying with the amount of carbon present in the steel and becoming more marked in the case of high-carbon than low-carbon steels. It is possible to keep the manganese down by the use of low manganese spiegel, and with low-sulphur steel its presence in excess

of 0.8 per cent, or its use to bring up the tensile strength in place of carbon, is dangerous on account of its very distinct hardening effect when above 0.6 per cent. In the commercial run of iron, where the sulphur varies, the practice is to allow the manganese to go as high as 1.1 per cent, and some authorities do not consider it dangerous unless above 1.0 per cent even with low sulphur. Manganese tends to neutralize the effect of sulphur and prevent the metal becoming red-short, and, to a limited degree the cold-shortness produced by phosphorus.

48. Chemical Composition of Early Rails.—It was supposed that the chemical character of the steel in the earlier rails accounted for their excellent wear.

The old English rails which gave such good service were expected to give analyses which would show steel of exceptional uniformity and purity. But this was found not to be the case and the following example of thirteen rails made by John Brown & Company, of Sheffield, England, is typical of the variation found in the steel of which these old rails were composed:

	Per Cent.	
Carbon	0.24 to	0.70
Manganese	.312	1.046
Phosphorus	.077	.156
Sulphur	.050	.155
Silicon	.032	.306

In 1881 Dr. C. B. Dudley, the chemist of the Pennsylvania Railroad, made an investigation to determine the relation between the chemical and physical characteristics of steel rails, and in a paper before the American Institute of Mining Engineers, proposed a formula for the correct composition of steel rails as follows:*

	Per Cent.
Carbon between .25 and .36; aim at	0.30
Phosphorus, not above	0.10
Silicon, not above	0.04
Manganese, between .30 and .40; aim at	0.35

* Trans. Am. Inst. of Mining Engrs., Vol. IX (1880–81), p. 321.

Dr. Dudley's conclusions, on account of the careful character of the investigation and high reputation of the road, were generally accepted as correct and for many years rails were made too soft.

49. Chemical Composition. Present Practice.—Owing to the exhaustion of the available low-phosphorus ores, Bessemer rail steel is now of necessity a high-phosphorus and low-carbon alloy, the mean carbon being about 0.50 per cent, while the phosphorus is limited to 0.10 per cent. Plain basic open-hearth rail steel is usually a low-phosphorus and medium unsaturated carbon alloy, as most of the phosphorus has been reduced by this process from its content in the ores and iron to 0.04 per cent or under. This permits in this class of steel rails carbon of 0.62 to 0.75 per cent.*

The impurity of sulphur was limited formerly to 0.075 to 0.08 per cent. The manufacturers now charge for this limitation of sulphur five cents extra per hundred pounds, and it is, therefore, being omitted from some specifications, although in most cases it is required that its content be reported.

The upper limits for the silicon content are placed quite generally at 0.20 per cent.

The following is the chemical composition specified by the American Railway Engineering Association for 100-lb. rails.†

Elements.	Per cent for Bessemer Process.	Per cent for Open-hearth Process.
Carbon	0.45 to 0.55	0.62 to 0.75
Manganese	0.80 to 1.10	0.60 to 0.90
Silicon, not to exceed	0.20	0.20
Phosphorus, not to exceed	0.10	0.04

50. Chemical Composition. Special.—The attention of railway engineers is being directed toward the development of alloy steel, or steel containing a percentage of various materials intro-

* See Proceedings Am. Soc. for Testing Materials, Vol. XI, 1911, P. H. Dudley, Ductility in Rail Steels.

† Supplement to Manual, 1914.

duced to give it special mechanical qualities. In general, however, on account of the higher cost of production, these steels are confined to use in special localities where the conditions are especially severe, as on the sharp curves under heavy traffic or in tunnels where it is a troublesome matter to inspect or renew the rails.

The requirements of steel alloy may be summarized as follows:

(1) High resistance to shock.

(2) High elastic limit.

(3) Resistance to abrasion.

Some of the alloys best known are manganese, nickel and chromium.

Manganese steel with C 0.77, P 0.06, Mn 9.93, Si 0.25 and Su 0.038 showed about one-third as much abrasion of the head as ordinary Carnegie Bessemer in a test, on the Norfolk and Western, lasting nineteen months.

Nickel steel has been used tentatively for railroad rails; but while it has the stiffness and resistance to wear which they require, too many rails have broken in use. We may hope that this treacherousness will be prevented. It is quite possible that a change in the percentage of nickel may give an entirely different record. The Mayari ore used by the Maryland Steel Company contains a natural percentage of chromium and nickel, and the results with rail made from this ore seem, so far, to be pretty good. The addition of the alloy is, however, in this case not very great, and the physical properties of the steel, while improved, do not vary in any considerable degree from the plain steel. The same is true of the titanium rail; in fact titanium steel, while generally treated under this head, is not strictly an alloy steel. The titanium under the usual practice goes into the slag and ordinarily there is no intention of producing titanium alloy steel.

51. Specifications.—A study of the specifications of the American Railway Engineering Association will afford a thorough knowledge of the present requirements for rails in this country.

The specifications, which reflect the latest thought, are noticeable for the increase in the number of physical tests over those

required in earlier specifications. A great many defects, such as piping of the ingot, can be adequately guarded against by proper physical tests, and in general it would appear desirable to leave the producer free in such cases to adopt his own methods of manufacture. Within certain limits, however, the specifications may well be drawn to exclude the practice which is known to result in defective material. The desirability of doing this is emphasized by the great difference in quality found in rollings from different mills, and in some cases for rails from the same mill, but rolled in different years. The specifications of the New York Central Lines are a good example of specifications drawn with a view to eliminating defective practice at the mill.

The trend of recent specifications is to increase the amount of inspection which is being given the rail at the mills. The plan of R. W. Hunt and Company of placing inspectors throughout the mill to watch the entire process of manufacture is evidence of this.

52. Lengths.—In a bulletin (August, 1909) of the International Railway Congress, this question is very fully discussed.

In Great Britain and Ireland the railways have been gradually increasing the length of rails, with a view to reducing the number of joints. Some railways still use rails 30 ft. long, and a few use 60-ft. rails, but a large number have 45-ft. rails, and it appears that this may be taken as a standard for the near future. The principal reasons for limiting the length, given by the engineers of different railways, may be summarized as follows: (1) Difficulty of straightening rails at the mills; (2) cost of manufacture; (3) difficulties of transportation; (4) expansion and contraction; (5) unloading and handling on the track.

In the United States the standard length is 33 ft., and the reasons given for limiting the length are, in general, similar to those noted above. Experiments have been made with rails of greater length, but on the whole these have not been satisfactory although the opinions expressed by some of the railways give 40 ft., 45 ft., 50 ft., and 60 ft. as admissible lengths.

The following interesting report from the Pennsylvania Lines is given in the bulletin:

In 1897 a continuous rail, 1050 feet long, made up of 35 80-pound 30-foot rails joined by angle bars with drilled holes and machine turned bolts (no provision being made for expansion and contraction), was laid in the eastbound main track, near Brighton, Pa. The ends were held by bent rails bedded in concrete, so placed as to bear against the ties. Special long and wide angle bars were used at the ends, fastened to the anchor ties with lag screws. The track was a tangent with stone ballast.

The rail crept and kinked out of line badly. An examination made in August, 1900, after three years' service, showed that the entire rail crept in the direction of traffic (eastward). At the west anchorage, the vertical holding rails had cut into the cross-ties forming the anchorage framework, while at the east anchorage there was a space of $1\frac{3}{4}$ inches between the vertical rails and the framework. All of the spikes were bent eastward, and both slots and spikes were badly cut. The bolts were all slightly sprung. The alignment at the joints was very bad.

53. Rail Failures.—During the agitation which resulted in the revision of the A.S.C.E. sections and the recommendations of the American Railway Association for new sections, three principal reasons were advanced as to the probable cause or the poor service of some of the later rails. It was claimed that the wheel loads in this country were exceeding the limits of strength of steel in the rail, and, without resorting to extraordinary methods of manufacture and consequently greatly increased cost, the rails could not be made to carry the loads imposed upon them with a proper degree of safety. The standard sections then in use were those of the American Society of Civil Engineers, and this design of rail, in the heavier sections demanded, was stated to be an impracticable one to roll.

The manufacturers of rails proposed these explanations as the real reasons which accounted for the failures of the rails in service. The railways, on the other hand, while admitting that the metal of the rails in some cases did not stand the heavy wheel loads, claimed that this was due to the fact that the steel was of poorer quality than that obtainable in rails of earlier make, and that sufficient care was not being given to the details of manufacture in the various processes at the mills. The increase in the number of rail failures of the type designated as "crushed heads" and "split heads" the manufacturers claimed

was caused by the metal breaking down under the excessive pressure of the heavy wheel loads, and the railways contended rather that they were due to some defect in the structure of the individual rails.

The adoption of the new specifications of the American Railway Engineering Association and the use of greater care in the inspection of the various details in the mill has been followed by a considerable improvement in the character of the metal. This improvement in the quality of the rails has been further increased by the change from Bessemer to open-hearth steel. The use of the new sections with the heavy flanges has resulted in a marked decrease in the base failures, which it is generally felt were caused by the strains produced in rolling and cold straightening due to the thin bases in the A.S.C.E. type.

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Steel Rails, W. H. Sellew, 1913, New York, pp. 463–500 (contains Standard American and English Specifications and bibliography for the years 1877–1912).

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CHAPTER VII

OTHER TRACK MATERIAL

54. Turnout. Switches.—Switches are generally made in 10-ft., 15- to 18-ft. and 25- or 30-ft. lengths. The 10-ft. switch is used in yards, for all other general uses a medium-length point is employed, but at ends of double track or at other places where trains pass over the switch at a high rate of speed it is necessary to lengthen the switch point, and 25 or 30 ft. has been found desirable.

Referring to Fig. 77, showing the 30-ft. switch point of the Pennsylvania Railroad, it will be noticed that the switch plates upon which the switch slides when thrown are recessed; in some cases pressed steel risers are used on these plates, or the plate may be flat. The result of recessing the plate or employing pressed risers is to elevate the switch rail slightly above the stock rail. This is important, as it is very evident that in a trailing point switch with the switch rail at the same height as the stock rail, considerable pressure must at times be exerted by a worn wheel, tending to widen the gauge of the main track rails.

The fact that many roads use switches with the switch rails at the same height as the main track rails does not demonstrate that such a tendency does not exist, while the experience of many trackmen has been that under certain conditions it may be an important factor in maintaining the switch in good condition.

A cast heel filler block is frequently employed and although this is not used on some important roads it is nevertheless of importance in strengthening the point and also enables a smaller switch angle to be used. A distance of $6\frac{3}{4}$ ins. would appear

to be about the minimum for the use of standard angle bars on the inside of the joint; where a heel block is employed, however, there is no good reason why the flangeway cannot be reduced to $2\frac{7}{8}$ ins. giving a heel distance for 100-lb. A.S.C.E. rail of $5\frac{5}{8}$ ins. It will be noticed that in the Pennsylvania switch a special inside splice is used with a heel distance of $5\frac{3}{4}$ ins.

The point of the switch is protected by the bend in the stock rail, but is nevertheless exposed to considerable wear. The use of manganese points is to be commended in places where the

FIG. 78.—" Economy " Switch Point.

ordinary steel will not stand the traffic. Manganese steel, while little used for rails on steam roads, is employed largely and with excellent results for switches and frogs.

In yards where the points wear rapidly on account of the constant switching on the ladder tracks the "Economy" separable switch points shown in Fig. 78 have given very good results. These points are cast of a special alloy and being made of a tough material will wear to a thin edge.

The Wharton switch, illustrated in Fig. 79, is a good example of a switch which does not require the main line to be broken.

These switches have to be taken at slow speed, and are only applicable in cases of side tracks that are not used frequently.

In entering the switch the portion of the tread of the inside wheels overhanging the head of the main rail is lifted up an incline by the elevating switch rail until the flange of the wheel can pass over the head of the main rail; the switch point on the other side at the same time guides the outside wheels into the siding. The trip-rail movement shown in the drawing throws the switch automatically if a train should trail through it on the main track while it is set for the siding.

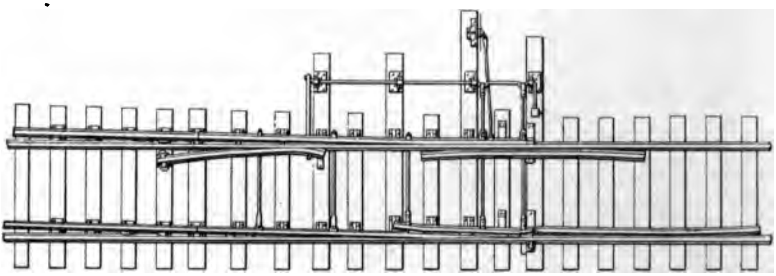


Fig. 79.—Wharton Switch.

The principal requirements of a switch stand may be summarized as follows:

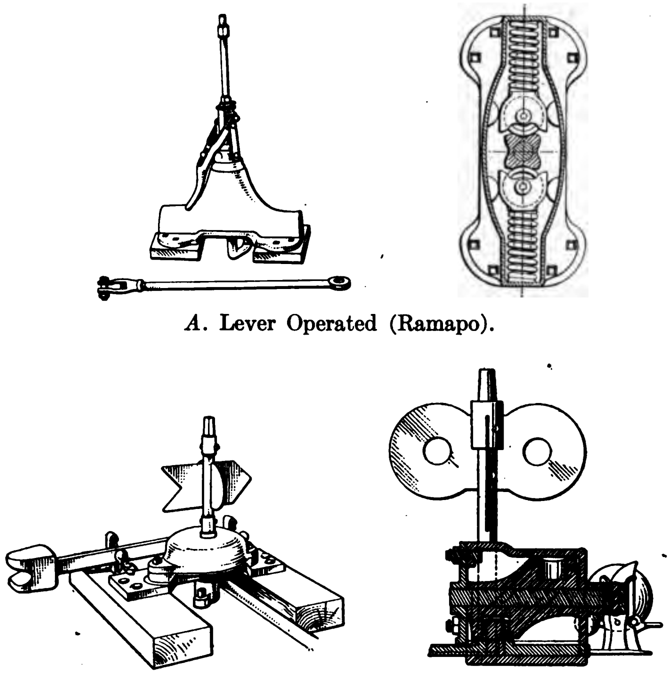
No switch stand which can be automatically thrown or operated by the switch being run through should be used in main-line tracks.

When a switch is manipulated by a stand, without bolt or other exterior locking, the rod should be held in position at dead center when switch is both open and closed, except where controlled by an interlocking device.

Stands are made to be operated by means of a lever connected directly to the standard (Fig. 80*A*), a gear (Fig. 80*B*), or a cam (Fig. 80*C*).

In the stand shown in Fig. 80*A* the switch can be run through without damage to the stand or the switch, and the

target and lamp always indicate the exact position of the switch points. The springs which hold the switch points against the stock rail require a pressure of approximately 2000 lbs. to start them, and if the points are thrown half way by cars trailing through the switch, they are snapped to the opposite stock rail,



A. Lever Operated (Ramapo).

B. Gear Operated (Century). *C*. Cam Operated (Odenkirk).

Fig. 80.—Switch Stands.

where they are held with equal pressure; at the same time the position of the target and lamp changes to correspond.

However, when the switch is thrown by hand, in the regular manner, the arrangement is such that the springs remain inoperative and the throw is accomplished positively and with only the

ordinary resistance incident to throwing the switch points from one position to the other. This is because the operator, when he raises the handle to throw the switch, releases, at the same time, the spindle from the automatic mechanism, and once raised, the handle cannot be relowered, or the switch locked, until the points have been fully thrown.

In some stands a breakable cross-arm is provided, and if the switch is run through when not properly set, this arm breaks without further damage to the stand or points. This is undesirable, as the stand will then give a wrong indication. It will be noted that with the spring mechanism described above when the points are run through they are thrown automatically and a correct indication is given by the target.

It will be observed that in the Odenkirk stand shown in Fig. 80*C* the cam locks the switch points in both the open and closed position at dead center, hence a train in passing over the switch has no effect on the switch stand lever.

55. Turnouts. Frogs.—Frogs are of two general kinds, rigid and spring. The rigid frogs are used in yards and also on the main line when the traffic through the turnout is heavy. In recent years the hard-center rigid frog has replaced to a considerable extent the spring frog for main line use. The plans of the frogs shown in Fig. 81 illustrate typical construction. Referring to the drawing of the rigid frog, the tongue filler between the lap and main rail is omitted on many frogs and frequently two fillers are used instead of the four shown. The heel filler or riser is of cast steel on this frog, but cast iron is used with good results for this filler in connection with an inverted T-rail riser.

Hard-center frogs are now being used in considerable numbers where the traffic is heavy. The general design of these is shown in Fig. 81*C*.

The rigid frog with a hard center is largely used on the main line of the Pennsylvania Railroad and other important roads. It appears to be a safer frog than a spring frog, as the latter during the winter may cause trouble on account of snow and ice accumulating in the mechanism. The principal objection to

the rigid frog, that of excessive wear, is overcome by the use of the hard center of manganese steel.

Spring frogs have been designed for main-line use to avoid wear and the jar of the wheel in going over the gap which of necessity occurs in the rigid frog. These are illustrated in the plan of the frog, shown in Fig. 81*B*. Referring to the latter plan, it will be noticed that the spring rail, unless opened by the wheels, is held closed by the springs. The plan shows two springs, whereas only one is often used. The two cast-steel fillers shown are sometimes replaced with one rolled-steel filler. The metal foot guard on many roads is replaced with a solid cast block.

The Conley frog with a raised wing to guide the wheel is used extensively in yards; with this frog no guard rail is necessary, as the point of the frog is protected by the extra elevated rail, which performs the same functions as the guard rail with the ordinary frog.

Fig. 82 illustrates a guard rail. A length of 16½ ft. was a common standard a few years ago, but now shorter lengths are considered good practice. Many roads use 11-ft. guard rails and the Ajax cast manganese guard rail shown in Fig. 83 is only 9 ft. long and appears to give good service, not only in yards and around terminals, but on the main line as well.

Guard rails were formerly spiked in place, but owing to the importance of securing them firmly to gauge are now generally fastened to the stock rail by means of clamps. The ends of the rail are sometimes beveled so as to prevent hanging brake beams or other defective equipment fouling the guard rail.

The flangeway of the guard rail is 1¾ in. when the gauge is standard; however, if the gauge is widened as would be the case when the frog is located on a curve, the flangeway must be widened by the same amount. The reason for this can be readily seen when it is remembered that the guard rail guides the back of the wheel and thus protects the point of the frog. If the guard rail is moved over when the gauge is widened it will carry both wheels with it, and the wheel at the frog would be pulled so far away from the point as to be liable to override the flangeway.

A. "Safety" Foot Guard.

B. Wharton Clamp.

Fig. 82.—Plain Guard Rail.

The general arrangement of the ties, switch and frog in a turnout is shown by Fig. 50, illustrating a No. 11 turnout. The distance from the point of the switch to the point of the frog

FIG. 83.—Ajax Manganese Guard Rail.

is called the lead. This is determined by the switch angle and the frog angle as shown in Fig. 84.

G = Gauge;
P = Theoretical point of frog;
D = Toe of frog;
C = Heel of switch rail;
AC = Length of switch rail;
AB = Lead;
F = Frog angle;
a = Switch angle.

If we extend PD and AC to intersect at I, then $DI = CI =$ tangent distance of lead curve.

The switch angle is determined by the length of the switch rail and the heel distance. For high speed it is obviously desirable to make this angle small and a longer point or switch rail

is used than for turnouts designed for slow speed. The heel distance was formerly limited by the room necessary for the angle bars, but where a heel block is used this distance can be reduced somewhat, as previously explained.

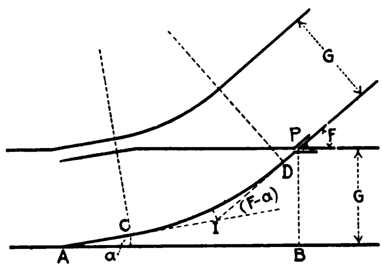


FIG. 84.—Diagram of Turnout.

Authorities differ as to the definition of the frog number. The American Railway Engineering Association defines it as one-half the co-tangent of one-half the frog angle.* (Fig. 85*A*.) On

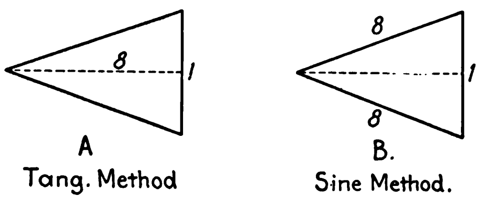


FIG. 85.—Definition of Frog Number.

the other hand, we find in Vol. 14, Bulletin 7 of the International Railway Congress, July, 1900, the following:

By a 1 in 8 crossing, most companies mean a crossing whose legs form the two equal sides of an isosceles triangle whose sides are eight times the length of the base, and it appears that this is the simplest method of description. (See Fig. 85*B*.)

* Manual, 1911, p. 85.

The first definition will give a frog angle of 7° 09′ 10″ for a No. 8 frog and the second definition gives 7° 10′ 00″.

There appears to be some question as to whether it is altogether desirable to give the frog angles in seconds on the plan. A frog can hardly be built closer than two or three minutes and an impression of accuracy is given that is foreign to the things we are dealing with. The use of seconds should, however, be employed in the calculations of the lead and of the dimensions of the frog.

Table VI shows the properties of frogs and switches and practical leads recommended by the American Railway Engineering Association.

Frogs as sharp as Nos. 5 or 6 are used where local conditions make it imperative. Nos. 8 or 9 frogs are generally used for turnouts in yards, terminals, and when local conditions make it imperative for main tracks to side tracks; Nos. 10 or 11 frogs for turnouts from main tracks to side tracks, between main tracks for movements against traffic and where local conditions make it necessary. Nos. 15 to 20 frogs should be employed for interlocked turnouts used for movements with the current of traffic. In general, no main line turnout should be installed for movements with the current of traffic unless interlocked, on account of the danger of derailment when running over a facing-point switch.

56. Derails.—Derails are used at interlocking plants, as will be explained in Chap. XV., and at outlying switches to prevent cars standing on the side track being moved accidentally too near the main track and thereby endangering trains. The earlier forms of derails consisted of an ordinary switch point or stub switch in the outside rail. Derails used at the present time generally leave the track unbroken, as with the Hayes derail. shown in Fig. 86, or the Wharton derail, which is similar in design to the Wharton switch. The use of the Wharton derail is confined principally to main line derails at interlocking plants; while at outlying switches and slow speed tracks a derail of the form shown in Fig. 86 is generally employed. This is connected with the switch stand to insure its being thrown when the switch on the track to which it belongs is operated.

TABLE VI

Theoretical and Practical Switch Leads

(Am. Ry. Eng. Assn. Manual, 1914) In all cases gauge is considered 4 ft. 8½ in.

	Properties of Frogs. Thickness of all Frog Points, 0½″.						Properties of Switches. For all Switches Thickness of Point = 0¼″ and Heel Distance = H = 6¼″.		Theoretical Leads.				
N = Frog Number.	F = Frog Angle.	W = Length Theoretical Point to Toe.	K = Length Theoretical Point to Heel.	Total Length.	Spread at Toe.	Spread at Heel.	S = Length of Switch Rail.	a = Switch Angle.	R = Radius of Center Line.	D = Degree of Lead Curve.	Distance Point of Switch Rail to Theoretical Point of Frog.	Cosure Straight Rail.	Closure Curved Rail.
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
	Deg Min. Sec.	Ft. In.	Ft. In.	Ft. In.	Feet.	Feet.	Ft. In.	Deg. Min. Sec.	Feet.	Deg. Min. Sec.	Feet.	Feet.	Feet.
4	14 15 00	3 2	5 4	8 6	0.79	1.32	11.0	2 36 19	112.26	52 53 56	37.05	22.88	23.29
5	11 25 16	3 7	6 5	10 0	0.71	1.28	11.0	2 36 19	183.22	31 40 24	42.77	28.19	28.55
6	9 31 38	4 0	7 0	11 0	0.66	1.16	11 0	2 36 19	273.95	21 01 58	48.11	33.11	33.38
7	8 10 16	4 5	8 1	12 6	0.63	1.15	16.6	1 44 11	364.88	15 47 19	61.94	41.02	41.24
8	7 09 10	4 9	8 9	13 6	0.59	1.09	16.6	1 44 11	488.71	11 44 40	67.47	46.22	46.42
9	6 21 35	6 0	10 0	16 0	0.67	1.11	16.6	1 44 11	616.27	9 18 27	72.24	49.74	49.92
9½	6 01 32	6 0	10 0	16 0	0.63	1.05	16.6	1 44 11	699.97	8 11 33	74.90	52.40	52.58
10	5 43 29	6 0	10 6	16 6	0.60	1.05	16 6	1 44 11	790.25	7 15 18	77.51	55.01	55.17
11	5 12 18	6 0	11 6	17 6	0.54	1.05	22 0	1 18 8	940.21	6 05 48	92.06	64.06	64.20
12	4 46 19	6 5	12 1	18 6	0.53	1.01	22 0	1 18 . 8	1136.34	5 02 38	97.25	68.83	68.96
15	3 49 06	7 8	14 10	22 6	0.51	0.99	33 ·0	0 52 5	1744.45	3 17 06	130.50	89.83	89.94
16	3 34 47	8 0	16 0	24 0	0.50	1.00	33.0	0 52 5	2005.98	2 51 24	135.95	94.95	95.05
18	3 10 56	8 10	17 8	26 6	0.49	0.98	33 0	0 52 5	2587.66	2 12 52	146.38	104.54	104.61
20	2 51 51	9 8	19 4	29 0	0.48	0.97	33 0	0 52 5	3262.98	1 45 22	156.35	113.68	113.76
24	2 23 13	11 4	23 2	34 6	0.47	0.97	33 0	0 52 5	4932.77	1 09 42	175.09	130.66	130.77

TABLE VI—*Continued*

THEORETICAL AND PRACTICAL SWITCH LEADS

(Am. Ry. Eng. Assn. Manual, 1914.) In all cases gauge is considered 4 ft. 8½ in.

PRACTICAL LEADS

N = Frog Number.	R_1 = Radius of Center Line.	D_1 = Degree of Lead Curve.			Rectangular Co-ordinates to the Quarter and Center Points on Gauge Side of Curved Rail, Referred to Point of Switch Rail as Origin.						T_s Tangent Adjacent to Switch Rail.	T_f = Tangent Adjacent to Toe of Frog.	L_1 = Distance Actual Point of Switch Rail to Theoretical Point of Frog.	Lead = Distance Actual Point of Switch Rail to Actual Point of Frog.	Closure for Straight Rail.	Closure for Curved Rail.
					X	X_1	X_2	Y	Y_1	Y_2						
I	XV	XVI			XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII
	Feet	Deg.	Min.	Sec.	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet		
4	110.69	53	42	24	17.74	23.44	29.75	0.97	1.67	2.79	1.03	0.00	37.77	37.94	1-23.60	1-24
5	174.34	33	19	57	17.78	24.54	31.27	0.95	1.61	2.62	0.00	0.82	42.26	42.47	1-27.68	1-28
6	265.39	21	43	04	19.07	27.13	35.15	1.01	1.74	2.72	0.00	0.66	47.73	47.98	1-32.73	1-33
7	362.08	15	52	29	26.72	36.93	47.11	0.97	1.71	2.74	0.00	0.19	61.81	62.10	1-13.89 1-27	1-14.11 1-27
8	487.48	11	46	27	28.37	39.91	51.45	1.02	1.78	2.91	0.30	0.00	67.65	67.98	1-16.40 1-30	1-16.60 1-30
9	605.18	9	28	42	28.75	40.98	53.19	1.02	1.76	2.75	0.00	0.57	71.91	72.28	1-16.41 1-33	1-16.59 1-33
9½	695.45	8	14	45	30.31	43.35	56.37	1.06	1.82	2.83	0.76	0.00	75.32	75.71	1-25.82 1-27	1-26 1.27
10	790.25	7	15	18	30.28	44.05	57.81	1.06	1.84	2.85	0.00	0.00	77.51	77.93	1-27 1-28	1-27.17 1-28
11	922.65	6	12	47	40.74	56.47	72.19	1.08	1.84	2.87	2.99	0.00	93.85	94.31	1-32.85 1-33	2-33
12	1098.73	5	12	59	43.99	60.65	77.28	1.15	1.90	2.91	5.33	0.00	100.30	100.80	1-23.88 2-24	3-24
15	1743.80	3	17	10	55.49	77.98	100.45	1.01	1.78	2.84	0.09	0.00	130.56	131.19	2-30 1-29.89	3-30
16	1993.24	2	52	59	58.16	81.76	105.35	1.04	1.82	2.87	1.56	0.00	136.90	137.57	1-29.90 2-33	1-30 2-33
18	2546.31	2	14	31	58.73	84.46	110.10	1.04	1.82	2.86	0.00	1.08	145.76	146.51	1-25.93 3-26	4-26
20	3257.26	1	45	32	61.84	90.21	118.59	1.08	1.88	2.93	0.44	0.00	156.59	157.42	1-26.92 2-27 1-33	3-27 1-33
24	4886.16	1	10	21	67.82	100.21	132.59	1.27	1.97	3.00	2.43	0.00	176.22	177.22	1-32.89 3-33	4-33

57. Crossings.—For crossings under 10 degrees movable-point frogs (Fig. 87) are used and generally these crossings are in the

FIG. 86.—Hayes Derail.

FIG. 87.—Wharton Movable Point Frogs with Manganese Steel Knuckle Rails and Points.

form of slip switches which permit not only a crossing of the tracks but enable trains to pass from one track to the other if so desired.

In Fig. 101 is shown a slip switch with movable-point frogs. The figure illustrates how trains can pass from one track to another track, or cross over the track as desired. These switches are used extensively at terminals, as shown in Fig. 194.

In the main line on important roads the crossing frogs are now nearly always of special steel. While the first cost of such frogs is much more than when carbon steel is used, this expense has seemed to be fully warranted by their longer life.

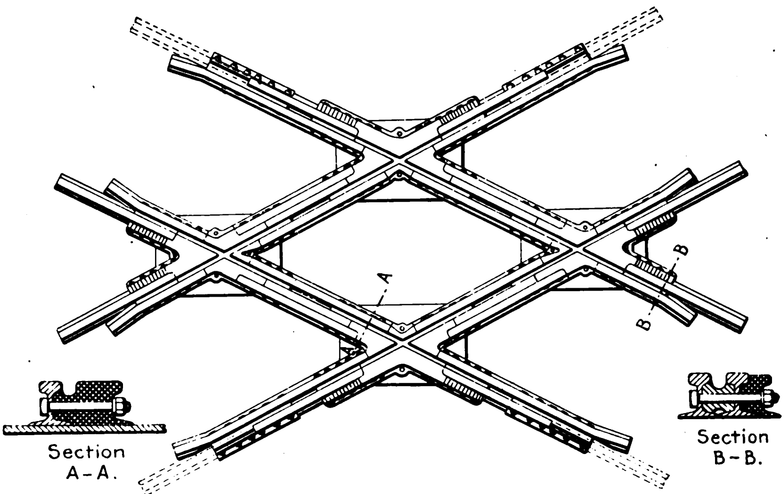


FIG. 88.—Hard Center Crossing.

Fig. 88 illustrates a hard center crossing. It will be noticed that the intersections are made of solid castings, which is a much more permanent construction than the bolted frogs formerly employed. The base plates are frequently omitted in the cast frogs. The connection between the castings and the rails is an important detail of construction, as the arms of the casting if too long or thin may break off under the heavy pounding of the traffic.

58. Joints.—The common angle bar is shown in Fig. 89. This figure also shows joints with deep girder flanges which add strength to the bar at the gap between the two rails where the entire bending moment must be carried by the bars from one rail to the other.

The Swedish government roads as early as 1876 used a deep girder splice bar with the depending flange vertical, instead of inclined under the bottom of the rail. The advantage of bringing the bottom of the flange under the rail is, that the vertical

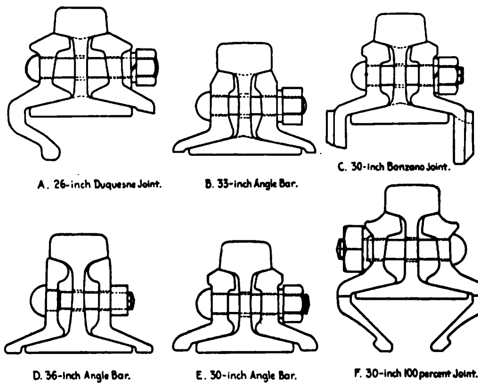


FIG. 89.—Joints Tested at Watertown Arsenal. (Am. Ry. Eng. Assn.)

axis of the bar lies inside of the bearing surface of the bolts and when the bar is subjected to load the tendency to rotate the flange outward is less than in the case of the vertical depending flange and a more stable construction is obtained.

Fig. 90 shows base-supported joints.

There seems to have been a return on many roads from the patented joint to the angle bar within the last few years. The most improved type of angle bar has a heavy head, and some of the roads use a high-carbon steel, heat treated and oil tempered to obtain the required strength.

In the low-carbon bars made by the Bessemer process, the carbon does not exceed .10 to .20 per cent. Most of the high

carbon steel angle bars furnished by the Cambria Steel Company have been between the limits of .45 to .55 carbon, not over .05 phosphorus and sulphur, and not over .70 manganese. All of these bars must be hot punched because of the high carbon, and the best results are obtained by oil treatment. The average

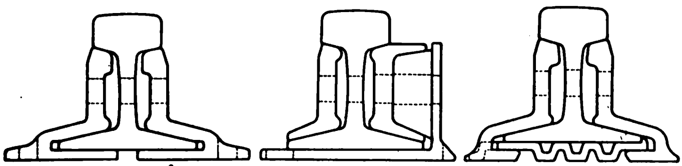


FIG. 90.—Base Supported Joints.

results obtained on a considerable tonnage of these bars were as follows:

Elastic Limit Lbs. per Sq.in.	Ultimate Strength. Lbs. per Sq.in.	Elongation. in 2 Ins.	Reduction of Area.	
61,300	93,250	20.4	29.8	natural
81,360	124,540	14.4	32.3	oil treated

The American Railway Engineering Association recommends the following:

High carbon steel joint bars.

Phosphorus, 0.04 per cent maximum.

Tensile strength, 85,000 lbs. per sq. in.

Heat treated, oil-quenched steel joint bars:

Phosphorus, 0.04 per cent maximum.

Yield point, 70,000 lbs. per sq. in.

Tensile strength, 100,000 lbs. per sq. in.

The Rail Committee of the American Railway Engineering Association several years ago made a series of interesting tests on rail joints at the Watertown Arsenal.

(1) Three joints of each kind were furnished, of which two were used for testing and the third joint was reserved for future use if needed.

(2) All joints were full-bolted. Several of the joints first tested had various sized openings between the rail ends. After the test of the first three joints, all other joints were changed so that the opening between the ends of the rails was as close to three-eighths of an inch as possible. The span between supports in the testing machine was 30 ins.

(3) One joint was tested with the load first applied to the base, in increments of 2000 lbs. until the limit of 32,000 lbs. was reached, and then the joint was reversed and the load applied on the head until the joint failed or the limit of the machine was reached.

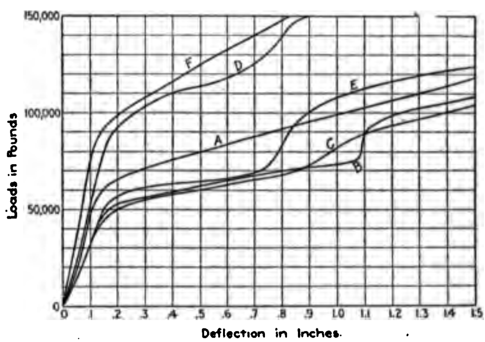


FIG. 91.—Diagram of Watertown Arsenal Tests on Joints. (Am. Ry. Eng. Assn.)

(4) The second joint was tested by first applying the load on the head and then reversing it, applying the load on the base, until the limit was reached.

(5) With the exception of the joints furnished by the Cambria Steel Company and Mr. A. Morrison, the joints were selected from material which had been furnished by the manufacturers to the railroad companies in the regular routine of business, and therefore fairly represent the material ordinarily furnished by the manufacturers.

Fig. 89 shows some of the joints tested and the results of the tests on these joints are presented in Fig. 91. The material in

the different splice bars varies so widely that it is difficult to judge of the value of the different designs. The excellent results obtained with the Dudley joint (Fig. D) is probably due to the high strength of the metal as compared to the other joints tested. (See Table VII.)

TABLE VII

PROPERTIES OF JOINTS TESTED AT WATERTOWN ARSENAL

(Am. Ry. Eng. Assn.)

Fig.	Rail.		Joint.					
	Weight lbs. per yd.	Section.	Area. Sq.in.	1 of 2 Bars.	Carbon. %	Manganese. %	Elastic Limit. Lbs. per Sq.in.	Ultimate Strength. Lbs. per Sq.in.
A	100	A.R.A. "B"	7.23	43.82	.25	.43	35,500	60,000
B	100	A.S.C.E.	4.60	13.40	.19	.47	41,000	60,500
C	100	P.S.	3.96	30.76	.63	.50	41,000	63,000
D	100	Dudley	3.37	9.36	.36	1.20	56,000	95,500
E	100	P.S.	4.91	13.99	.33	.43	39,500	60,500
F	100	A.S.C.E.	13.60	47.20	...	...	41,000	87,500

In examining the functions the joint performs in carrying the load from one rail to the other, Dr. Dudley has observed that the splice bars, by fitting tightly to the inclined surfaces of the head and base of the rail, are able by their friction to transmit large horizontal strains from one rail to the next. The proportion of the bending moment of the rail transmitted to the splice bar by this means is important in determining the correct proportions of the joint.

To determine the friction of the bar, tests were made at the Watertown Arsenal in 1904. There was first made a series of track observations on the Boston and Albany Railroad at Faneuil station, near Boston, to determine the resistance of nuts on bolts of splice bars (as found in the track) against further tightening.

Tests were made with a wrench 33 ins. long, the resistance against tightening being shown by the force required at the end of the wrench to turn the nuts forward. The average of 60 observations was 52 lbs. on a 33-in. wrench.

Tests were then made at the arsenal on the frictional resistance of two 6-hole splice bars on two sections of 6-in. 100-lb. rail. Spring nut locks were used under the nuts, $\frac{3}{4}$-in. bolts, 10 threads per inch, length of wrench used 33 ins. The results of the tests are shown in Table VIII.

TABLE VIII

FRICTIONAL RESISTANCE OF SPLICE BARS

(Watertown Arsenal)

Tightening Force Applied to Wrench (Pounds).	Frictional Resistance of Joint	
	Initial (Pounds).	Continuous Movement (Pounds).
50	37,500	33,800
75	46,900	44,700
85—5 bolts	72,800	65,500
110—1 bolt	72,800	65,500
50	31,000	28,600

The maximum pull applied to five of the bolts in the third test, 85 lbs. on a 33-in. wrench, was the limit of strength of the bolts. This pull on the wrench caused a permanent elongation of about .06 to .10 in. on each of the five bolts. The sixth bolt resisted a pull of 110 lbs. of the wrench without material elongation.*

After making observations on the frictional resistance in these tests, the first test, with bolts tightened to 50 lbs. pull, was repeated.

The splice bars were then used on one piece of rail, using four bolts, the nuts of which were tightened with a pull of 50 lbs. on a 33-in. wrench. The initial resistance was 50,900 lbs. and movement continued under 31,200 lbs.

Tests with four bolts in one piece of rail, with 50 lbs. pull on the wrench, were repeated with an initial resistance of 59,200 lbs. The movement continued under 41,600 lbs.

* The tendency is now to use bolts of steel with an elastic limit of 75,000 lbs. instead of the low carbon steel formerly employed for this purpose.

Dr. P. H. Dudley found that a well-fitted splice bar for a 5-in. rail required over 4000 lbs. per linear in. of one-half the length of the bar to overcome the friction in the rail ends, and for 90-lb. and 100-lb. 6-in. rail, 4500 and 4800 lbs. respectively.

We are probably not warranted in taking the frictional resistance of the joint at more than 40,000 lbs.; nor can the friction between the rail and the splice bar be well increased by the use of special joints, without at the same time increasing to an undesirable extent the stresses in the rail, caused by sudden changes in temperature.

It will be seen that the frictional resistance may cause an initial tensile stress of about 4000 lbs. per square inch in the 100-lb. rail at times of a sudden fall in temperature.

The tension set up in rails of lighter section in falling temperatures, before they render or give in the splice bars, is considered by Dr. Dudley to be important and indirectly responsible for a large number of the cracked or broken rails which occur during falling temperatures.

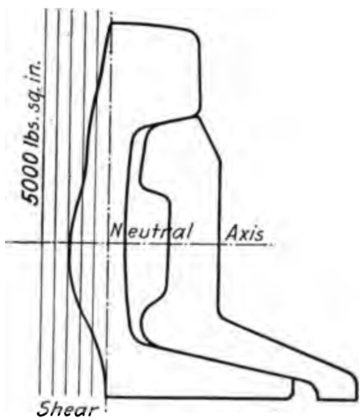


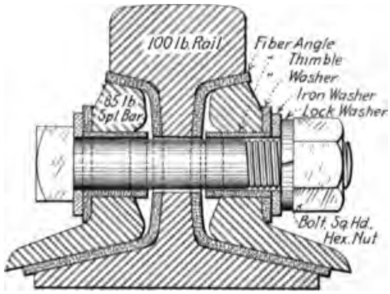
FIG. 92.—Shearing Stress in 100-lb. A.S.C.E. Rail and Angle Bar. (Total shear in section, 24,000 lbs.)

If we consider the effect of frictional resistance between the splice bar and the rail, it is apparent that the bar shown in Fig. 92 will act as an integral part of the rail until the longitudinal shear at the surfaces of contact of the rail and the bar exceeds the resistance caused by friction on these surfaces. This resistance for a 20-in. splice bar may be taken as 4000 lbs. per linear inch for the entire joint, of 1400 lbs. per square inch for the upper surface of contact, and 500 lbs. per square inch for the lower surface of contact.

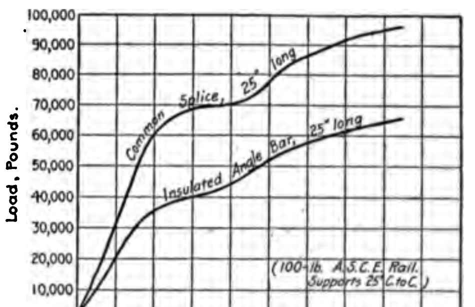
It is seen from the figure that the surface friction is sufficient to carry a total shear at the section of 24,000 pounds and it

would appear that the maximum bending moment in the rail would be transmitted to the splice bars without slipping.*

The deflection curves of Fig. 91 are characteristic of most joint tests and show a well-defined point in the curve similar to



A. Insulated Angle Bar.



B. Tests of.

FIG. 93.—Insulated Joints.

the elastic limit in the ordinary bending test, where the load rapidly drops off. It seems that at this point slipping takes

* As the vertical shear is equal to the horizontal shear this would correspond to a wheel load of 48,000 lbs., or by taking a dynamic augment to the static wheel load of 60 per cent an equivalent static wheel load of 30,000 lbs., corresponding to a static axle load of 60,000 lbs.

place between the joint and the rails and most of the load is then carried by the bar riding on the bolts.

Between the two rails the splice bars must carry the entire moment, and unless the strength of the bar is made sufficient for this there results an excessive deflection at this point.

An insulated joint is shown in Fig. 93*A*. In the earlier types wooden insulation was used, but fiber is now generally employed. On account of the low crushing strength of the insulating fiber as compared with that of steel, these joints require considerable attention from the trackmen to keep the track in proper line and surface at the places where they are used. Fig. 93*B* shows comparative tests on insulated and uninsulated angle bars.

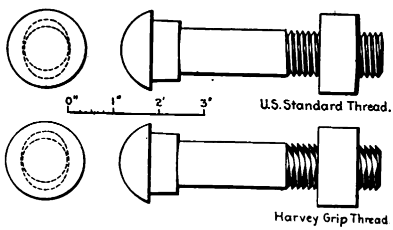


Fig. 94.—Track Bolts.

Compromise joints are used to bring the tops of different or worn sections of rails to the same level.

59. Bolts.—The bolt used in the joint is shown in Fig. 94. The Harvey grip thread shown on one of the bolts of the plan is a specially cut thread which acts as a nut lock and prevents the nut becoming loosened in service.

Bolts may have cut threads or rolled. Those in the figure are cut and when rolled the shank of the bolt is smaller in diameter than the thread.

The bolts in the joints are placed with the nuts alternately on the inside and outside of the rails except where the rails are less than $4\frac{1}{2}$ ins. in height, in which case the nuts are placed on the outside. The joints in one line of rail are generally placed opposite the middle of the rail on the other line of the same track.

The American Railway Engineering Association recommends the following for the chemical composition and strength of track bolts:

Medium Carbon Steel Track Bolts:
- Phosphorus, 0.04 per cent maximum.
- Tensile strength, 55,000 lbs. per sq. in.

Heat-treated Steel Track Bolts:
- Phosphorus, 0.04 per cent maximum.
- Yield point, 75,000 lbs. per sq. in.
- Tensile strength, 100,000 lbs. per sq. in.

60. Nut Locks.—The customary form of nut lock is the spring washer. This is shown in Fig. 95. The real advantage of the

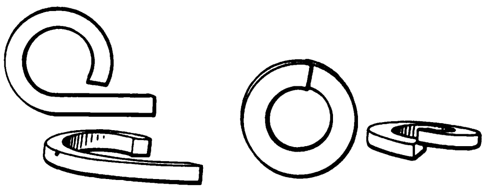


Fig. 95.—Verona Nut Locks.

spring washer lies in the fact that it not only tends to prevent the nut backing off from the bolt but it takes up wear in the splice bar and keeps the joint tight. As a matter of fact loose bolts in joints are generally due to this wear rather than the nuts turning on the bolt.

The spring washer to be of any real value should be made from steel of a high grade and uniform temper. The following chemical composition has been found satisfactory:

	Per Cent
Carbon	1.00
Phosphorus	.03
Sulphur	.03
Silicon	.10
Manganese	.50

Irregular carbon will result in breakages, or too many soft springs, which will become set solid after being tightened. The permissible variation in carbon should not exceed ten points either way from the figure given above.

61. Spikes.—Rails should be spiked in full with four spikes to each tie. The outside spikes of both rails should be on the same side of the tie, and the inside spikes on the opposite side of the tie. The inside and outside spikes should be separated as far apart as the face and character of the tie will permit. The ordinary practice is to drive the spikes $2\frac{1}{2}$ ins. from the outer edge of the tie.

In this country the ordinary nail spike is generally used for fastening a rail to a wooden tie. The most important objections to the spike, are: first, in the soft-wood tie the spike does not hold with sufficient firmness to keep the rail securely to the tie; second, in driving the spike into the softer woods the fibers are broken to an unusual extent. As a result they do not withstand lateral pressure of the rail, and consequently the spike hole is rapidly increased to such an extent that the spike no longer holds. Water collects in the enlarged hole and decay sets in.

When a spike has been redrawn from the tie on account of relaying the rail or other causes, a wooden tie plug should be driven into the spike hole to prevent water collecting in the hole. The tie plugs should be creosoted to protect the exposed fibers of the tie which have been cut by the spike, and are therefore particularly susceptible to decay. This is especially important in the case of a treated tie where the spike hole frequently reaches through the region penetrated by the treatment and exposes the untreated part of the wood.

Fig. 96 shows the dimensions of the common spike.

The screw spike, Fig. 97, is beginning to attract serious attention from American Engineers, and over 730 miles of screw-spike track is now in service in this country.

Apparently the French railways were about the first in Europe to begin the use of the screw spike (tirefond) as a rail fastening. Commencing about 1860 they rapidly adopted it as a standard and it is to-day universally employed by the large systems.

While the German, Austrian and Belgian railways did not adopt this style of fastening as early or as generally as those of France, and the use of the hook is quite widespread, they use the screw spike extensively. In 1899 the general employment of the screw spike on all lines of the system was prescribed for the Prussian Government Railways.

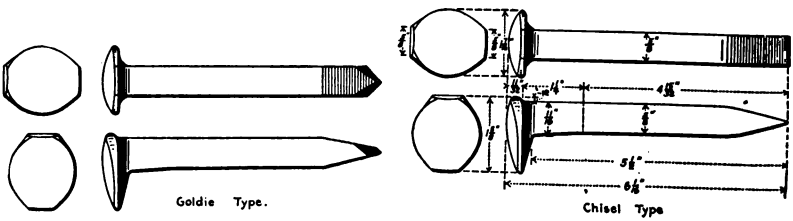


FIG. 96.—Common Spikes.

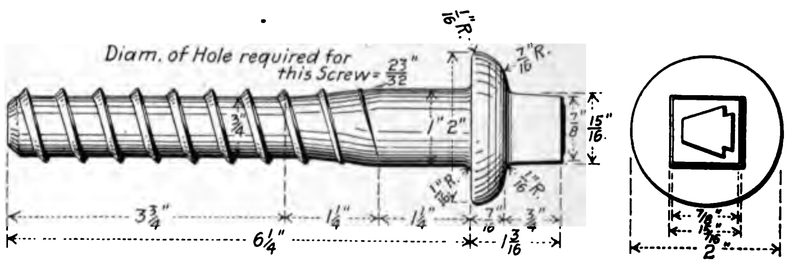


FIG. 97.—Screw Spike. (Am. Ry. Eng. Assn. Cushing.)

In Great Britain most of the railroad systems use bull head rails which do not rest on the ties, but on heavy-cast iron chairs. The fastenings for these are generally two metal spikes and two wooden trenails. The London and North Western Railway use two screw spikes instead of the trenails; but it does not appear that the English roads, as a rule, consider the screw spikes necessary.

That the screw spike is not thoroughly perfected is shown by the devices which have been employed in Europe to strengthen

it, as the Collet wooden screw trenail, and the Thiollier helical lining. In this connection Mr. Cushing states,* referring to recent tests on the Pennsylvania:

Some of the same difficulties are arising in the new tests, which clearly show that a screw spike is not a successful device for securing rails to wooden ties, unless a successful method of repairs from time to time can be devised, which will enable one to "cure" the screw spike when it becomes loose, which it does inevitably in the course of time in many instances, under heavy traffic and severe conditions.

62. Tie Plates.—The general tendency at the present time is more and more toward the use of tie plates. With the introduction of the treated tie it is necessary to adopt some means to protect the wood from wear at the rail bearing on account of the longer life of the tie.

The objections which have been made to tie plates are, first of all, that they buckle severely. This, however, has taken place only when the plates were too thin, and the present plates have in general ample strength to resist buckling.

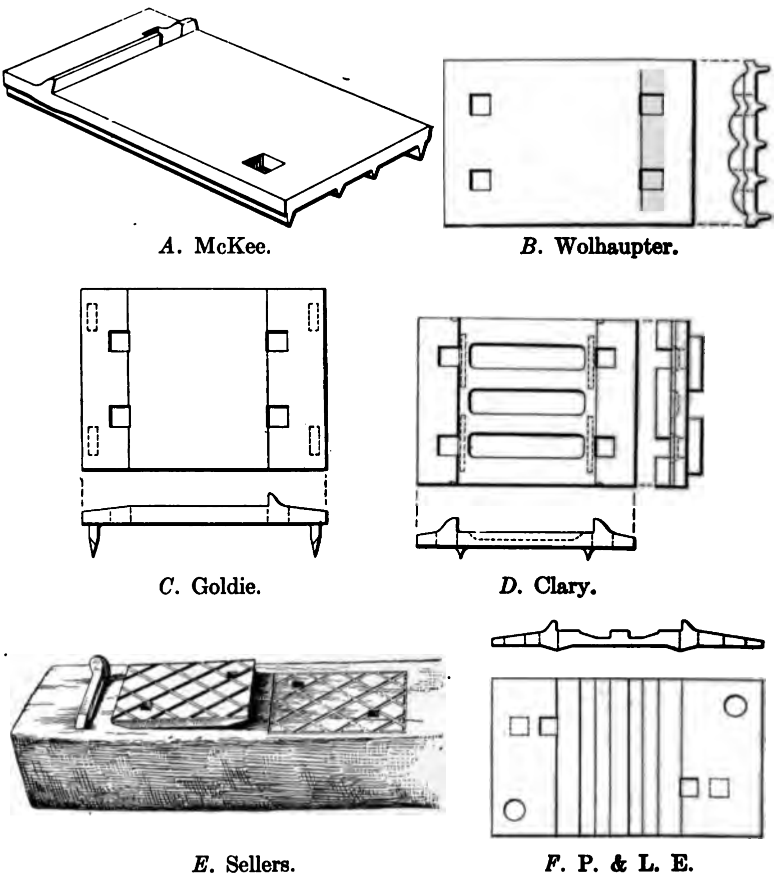
Plates were formerly made with the idea of being anchored to the tie so as to prevent the communication of the motion of the rail to the plate. As a result, we have a large number of different forms of plates, provided with prongs, spines or flanges on the bottom, which are pressed into the tie either by the weight of the passing load or before the rail is laid. (See Fig. 98.)

The chief objection which has been made to plates, particularly in connection with the use of softer woods, is that not only do they not aid in preventing the wear of fibers, but they actually assist the rail in causing this wear. This is clearly shown in Fig. 99. The general tendency on the Continent has been toward adopting more and more rigidly flat plates, with firm fastenings. The almost universal adoption of this principle is very striking at the present day.

On the French Eastern the rail rests on the tie without metallic plates, except on very sharp curves (of 984.25 ft. radius and under).

* Experiments with Treated Cross-ties, Wood Screws, and Thiollier Helical Linings, W. C. Cushing, Proceedings Am. Ry. Eng. Assn., Vol. 15, 1914, p. 265.

Plates of poplar or felt are placed under the rail, solely to protect the wood against the mechanical action of the base. These



A. McKee. *B*. Wolhaupter.

C. Goldie. *D*. Clary.

E. Sellers. *F*. P. & L. E.

Fig. 98.—Tie Plates.

plates are compressed before being used, so that they will not be further compressed under the pressure of the rail. The plates

are furnished 0.28 in. thick, and the compression brings them to 0.16 in.

The ties are adzed at the treating plant so that a place is left for this flat wooden shim. When the track is laid, the shim is placed in position and screw spikes are screwed into the tie. In the course of time the motion of the rail wears out this shim, and a new one is substituted by giving the screw spike one or two upward turns. A new plate is then shoved in endwise and the screw is fastened. The length of life of one of the modern

FIG. 99.—Wear of Tie under Tie Plate. (Bureau of Forestry.)

shims on the main-line tracks, such as that of the French Eastern from Paris to Strassburg, is about one and one-half to two years.

Dr. Von Schrenk gives the theory upon which this wooden plate is used as follows:*

The principal function of the plate has been said to consist of preventing the wear of the fibers of the tie immediately under the rail base. This wear consists in the actual breaking of the wood fibers under a grinding and tearing action rather than in crushing them.

In considering the function of the tie plate we have three bodies to deal with: the tie, the tie plate, and the rail. Motion might conceivably take place either between the rail and the tie plate or between the tie

* Cross Tie Forms and Rail Fastenings, with Special Reference to Treated Timbers, Forest Service, Bulletin No. 50.

plate and the tie. When a metal tie plate is used on the hard-wood tie, and is successfully anchored in it, the tie plate and the tie act as one body, over which the rail moves back and forth. As soon as the tie plate loses its holding power, however, the chances are that when the rail moves across the tie the tie plate will oscillate back and forth in unison with the rail. This results in breaking the wood fibers underneath the plate. Where a wooden plate is used, it adheres so closely to the wood that when the rail moves across the tie the wooden plate and the wooden tie are liable to act as one, even though the tie plate is not anchored to the tie.

The Forest Service tests on the Chicago and Northwestern and Northern Pacific tracks have not shown results favorable to wooden tie plates. The results thus far have been that the plates split badly. It has been thought, however, that this is largely due to the poor manner in which the plates were placed.

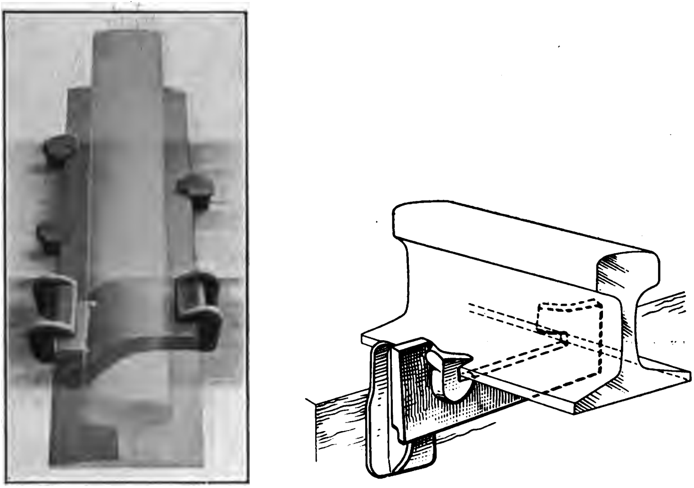
Some of the more recent metal plates in the United States have been made with the idea of fastening the tie plate to the tie with two screw spikes and using two common spikes to hold the rail down (Fig. 98*F*). This seems to be in accord with the latest thought, both on the Continent and in this country, that the plate must be held securely to the tie and whatever motion takes place will be between the plate and the rail rather than between the plate and the tie.

63. Anti-Creepers.—With the increase in density of traffic and as second, third and fourth tracks have been built limiting the direction of traffic, there has developed a growing tendency for the rail to creep or move in the direction in which the traffic moves. On account of the joint ties generally being spiked through slotted holes in the joint, these ties move with the rail, with the result that correct spacing of the adjacent ties is not maintained.*

To overcome this difficulty numerous devices are used for anchoring the rails to the ties. These are generally fastened to the base of the rail and bear against the side of the tie; when employed in sufficient numbers they are efficient in preventing the movement of the rail and reduce the expense of maintaining the track.

* See article 74, some roads are experimenting with unslotted joints.

Fig. 100 shows different types of anti-creepers and Fig. 101 is a view of the tracks of the Pennsylvania at its New York terminal, where anti-creepers are employed. This figure also illustrates the joint used by this company and a hard center frog. Double-shoulder tie plates have been used with considerable success in preventing the movement of the rail.



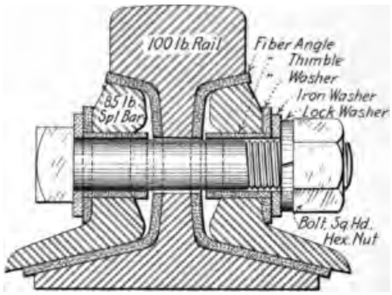
A. P. & M. *B*. Vaughan.

FIG. 100.—Anti-Creepers.

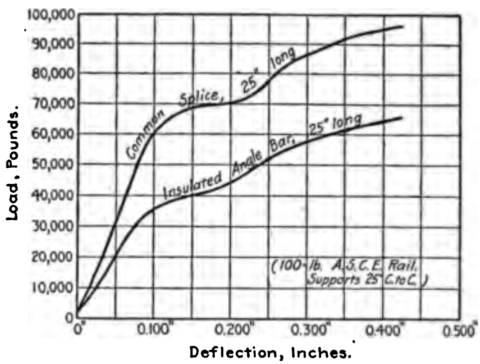
64. Bumping Posts.—Fig. 102 illustrates different types of bumping posts. The rail in the Ellis post is anchored down ahead of the post by four $1\frac{1}{2}$-in. anchor rods, extending into the ground 5 ft. 6 ins. to an anchor timber, and the resulting reaction when the car hits the post is supposed to be vertical. The rails next the post are connected to the adjacent rails by extra long splice bars with eight bolts to each pair of splices. In the Hercules post, a coil spring is placed back of the bumping surface with the intent gradually to absorb the shock given by the car. Wheel stops consisting of a series of corrugations over which

would appear that the maximum bending moment in the rail would be transmitted to the splice bars without slipping.*

The deflection curves of Fig. 91 are characteristic of most joint tests and show a well-defined point in the curve similar to



A. Insulated Angle Bar.



B. Tests of.

Fig. 93.—Insulated Joints.

the elastic limit in the ordinary bending test, where the load rapidly drops off. It seems that at this point slipping takes

* As the vertical shear is equal to the horizontal shear this would correspond to a wheel load of 48,000 lbs., or by taking a dynamic augment to the static wheel load of 60 per cent an equivalent static wheel load of 30,000 lbs., corresponding to a static axle load of 60,000 lbs.

the wheels pass are sometimes used in place of a bumping post and a covering of several inches of sand over the rail has been employed where the momentum of the moving train does not have to be overcome in a short distance.

A. Ellis.

B. Buda.

FIG. 102.—Bumping Posts and Wheel Stop.

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C. Hercules.

D. Saunders Wheel Stop.
FIG. 102.—Bumping Posts and Wheel Stop.

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CHAPTER VIII

BALLAST

THE principal function of the ballast is first to distribute the pressure from the ties to the grade and second to provide drainage and prevent water collecting around the ties. Water if retained in the ballast will cause the track to heave under the action of the frost and will also result in rapid deterioration of the ballast itself due to the churning action of the ties. The ballast should be composed of a material sufficiently durable to be able to resist the action of the ties and the tools used in tamping, without undue breaking up and pulverizing. It should be heavy enough and composed of large enough particles to prevent its being disturbed by the draft from rapidly moving trains and giving rise to objectionable dust.

As will be seen from the description of the various kinds of material used for ballast, the engineer has in most cases some choice in the selection of the ballast he may employ. This should be borne in mind and a careful investigation made of the materials the country affords before a final selection is made.

65. Kinds of, for First-class Track.—The following materials are suitable for first-class track: Crushed stone, slag and gravel.

Broken stone is generally considered the best material for ballast. It should be made from a hard, tough and durable stone as limestone, trap or granite. It should be screened in revolving screens and be free from dirt, dust, rubbish and small particles. It is largely used on account of the excellent drainage it affords and its freedom from dust.

Slag in many cases furnishes a ballast nearly as satisfactory as crushed stone and finds extensive use on roads in the vicinity

of furnaces and steel mills. The best product is obtained by crushing as in stone ballast. Granulated slag, which is the flux from the furnace broken down while hot with a water jet, is not desirable for first-class track, but a great deal of it is used for ballast on side tracks and for the first lift on new track.

Gravel ballast is very largely used, probably on account of its relative cheapness. While it affords an excellent riding track when first surfaced, it does not give as good drainage as stone or slag, and the track requires more attention than with stone. However, when the ballast is composed of coarse and clean gravel the results obtained are fairly satisfactory. Gravel should be screened or washed if prevention of dust is an object.

Screening has been used on the Pennsylvania Lines and on the Lake Shore for gravel containing a considerable proportion of sand. Where the bank contains much clay or loam the gravel may be washed. Instead of screening or washing to get rid of the dust some roads oil the ballast. The sprinkling is done from a flat car arranged with pipes over the roadbed and the oil can be applied at a speed of about 4 miles per hour.

66. Kinds of, for Branch Lines.—For branch lines and slow-speed traffic an inferior grade of gravel or granulated slag may be used. Cinders, sand and stone screenings are also applicable to this class of track. Cinders, which are obtained from the coal burned in the locomotives, are remarkably free from frost and are frequently used in wet places where it is necessary to give the track attention during the winter season. Burnt clay, which is being employed extensively in the West, has been used for some time in England and on the Continent. It is very light and is about equal to screened locomotive cinders.

The clay used for this purpose should not contain too much sand. The material should be thoroughly burned, or it will have a tendency to absorb too much water.

Clean sand will give good drainage, but it is so light that it drifts readily. To obviate this it is sometimes covered with a layer of broken stone as in India. Windbreaks of bushes are used on the Siberian Railways to prevent the drifting of the ballast, and on the Egyptian State Railways through the desert

the track is placed low enough to overcome this difficulty, the top of the ties being level with the surface of the ground.

Other materials are used locally for ballast, as chert, chats, disintegrated granite, shells, etc. Chert is a disintegrated rock found in the South. Chats are the tailings from mills in which zinc and lead ores are separated from the rocks in which they occur. This material is composed of particles about ¼ in. in size. Disintegrated granite is used in the Rocky Mountain territory and shells, as oyster shells, in the vicinity of the Coast.

Earth or "mud" ballast is composed of the natural soil along the road. The first cost of this material is low, but it is very expensive to maintain. Unless of a sandy nature its use is practica'' prohibited except for the lightest traffic, as it is almost impossib keep the track in safe condition during wet seasons an he oming out of the ground. In hot weather hen any work is done upon it it become intole ab

67. Sub-Ballast.— n found that stone ballast when resting directly on the subgrade will break the surface of the roadbed and prevent the water, which passes through the ballast readily, draining off, with the result that mud pockets are formed and the oil works up into the ballast, destroying its efficiency. This difficulty is overcome by ir oducing a layer of ballast of small particles between the st and the grade. Gravel or cinders are suitable for that pur e, and while the stone will enter this layer of sub-ballast to some extent, no harm is done, as the water is not expected to drain off of the surface of the sub-ballast, but passes through it t the surface of the roadbed, which being protected from the s p particles of the stone ballast, preserves its original surface.

Gravel or cinder is not objecti able for first-class track when used in this manner, as it is covere vith from 6 to 12 ins. of stone, which gives the requisite draina under the ties and prevents the dust rising from the finer ballast upon which it rests.

68. Sections.—The sections shown in Fig. 22 of the Pennsylvania roadway illustrate good practice in the use of stone ballast.

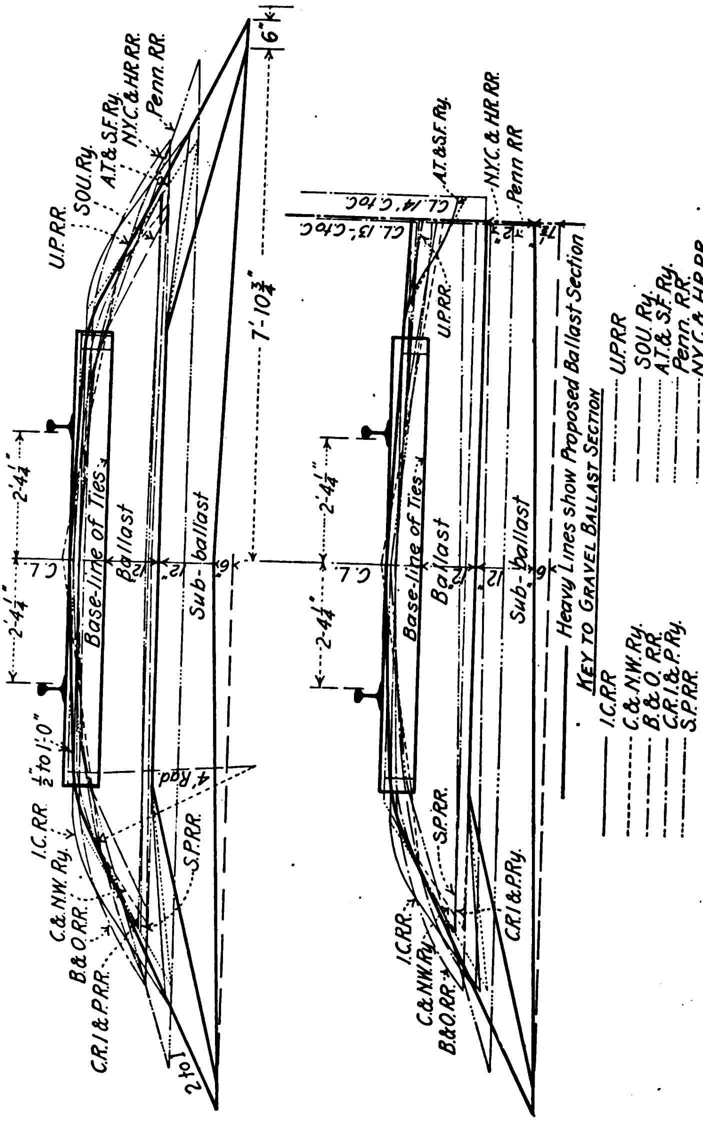


FIG. 103.—Composite Drawing of Various Ballast Sections. (Am. Ry. Eng. Assn.)

With gravel ballast a somewhat flatter slope is desirable. This is also necessary with cinders, chats, chert and granulated slag, where the slope should be about 3 to 1.

Fig. 103 shows a composite drawing of the ballast sections of various roads with the sections for single and double track proposed by the committee on Ballast of the American Railway Engineering Assn., indicated in heavy lines.*

69. Specifications.—The general requirements of the specifications for the different kinds of ballast may be summarized as follows:

Stone ballast should be clean and durable. It should break with an angular fracture when crushed and the pieces should pass in any position through a 2½-in. ring and should not pass through a ¾-in. ring.

The best grade of gravel ballast should not contain more than 2 per cent of dust or 40 per cent of sand. When it contains more than these percentages it should preferably be washed or screened.

Gravel for branch lines may contain as much as 3 per cent of dust or 60 per cent of sand before it is necessary to screen or wash it.

Slag ballast should be free from dirt, dust and the product from the mill; if not granulated (quenched in water), it should be crushed to the same size as stone ballast.

Stone screenings is a by-product of the crusher and is therefore made from the same quality of stone as stone ballast. The maximum size should not exceed pieces which will pass through a revolving screen having ¾-inch holes.

Burnt-clay ballast should be made of gumbo or other suitable clay free from sand or silt. The material should be burnt hard and thoroughly, and the absorption of water should not exceed 15 per cent by weight.

70. Physical Tests.—The physical tests for stone ballast recommended by the American Railway Engineering Association are as follows:

* Proceedings Am. Ry. Eng. Assn., Vol. 15, 1914, p. 972.

(*a*) Weight per cubic foot.
(*b*) Water absorption in pounds per cubic foot.
(*c*) Per cent of wear.
(*d*) Hardness.
(*e*) Toughness.
(*f*) Cementing value.
(*g*) Compression test.

The advantage of using approved physical tests of stone for ballast is to determine the character of the stone and its fitness for ballast without the expense of opening quarries and using the stone before it is known whether it will be suitable for ballast or not. Without some method of determining this by physical tests, railroads will undoubtedly be put to considerable expense by opening quarries and applying stone ballast, which in some cases will have to be replaced with better ballast from other quarries.*

FIG. 104.—Page Impact Testing Machine.

In the test for toughness, i.e., the ability of the stone to resist fracture due to impact, the office of Public Roads use the Page impact machine, shown in Fig. 104. This machine consists essentially of a 2-kilogram hammer which is guided by two vertical rods. This hammer does not strike the specimen to be tested directly, but

* For the description of the physical tests of stone for ballast as recommended by the American Railway Engineering Association and full instructions as to how the samples should be obtained and shipped to the Government for the test which is made free of charge at the office of Public Roads, see Proceedings, Vol. 11, Part 2, pp. 910–914, and Report of the Ballast Committee for 1912.

when released strikes a plunger made of armor-piercing steel with a spherical end and the blow is delivered through this plunger. The test piece rests on an anvil of hard steel. The test consists of a 1-centimeter fall of the hammer for the first blow, and an increasing fall of 1 centimeter for each succeeding blow until failure of the test piece occurs. The number of blows required to cause failure is used to represent the toughness.

Rocks which have a toughness which runs below 13 are called low; from 13 to 19, medium; and above 19, high.

For gravel ballast, the American Railway Engineering Association recommends that average samples of about 1 cu.ft. each should be selected from the pit. To separate the sand and dust from the gravel use a No. 10 screen made of No. 24 wire and to separate the sand from the dust use a No. 50 screen of No. 31 wire. The percentage of gravel, sand and dust should be measured by volume, as follows:

$$\text{Per cent of sand} = \frac{S}{G+S+D}.$$

where S = Volume of sand;
G = Volume of gravel;
V = Volume of dust.

71. Cleaning.—Under usual conditions, no ballast, except stone or hard slag, should be cleaned.

For stone ballast the American Railway Engineering Association recommends that the cleaning should be done with ballast forks or screens. The shoulder should be cleaned down to subgrade and between the ties to the bottom of the ties. Stone ballast should be cleaned in terminals at intervals of one to three years, in heavy traffic coal and coke lines at intervals of three to five years, and for light traffic lines at intervals of from five to eight years.

Fifteen to 25 per cent of new stone ballast should be applied when cleaning.

Keeping the ballast clean from weeds requires considerable time, especially in wet seasons. In recent years experiments have

been made for killing weeds by burning or by spraying. The apparatus used for burning consists of a flat car carrying a suitable pipe by means of which the flame is directed on the roadway. If a spray is employed to destroy the weeds, the spraying compound is carried in a tank car and distributed automatically over the ballast as the car moves along the track.

Other methods have been tried, as the use of electricity on the Illinois Central.

72. Handling and Distributing.—Ballast was formerly unloaded by hand or by means of a plow which was pulled over the cars either by the locomotive or an unloading mill. The unloading mill consists of a small stationary engine mounted on a flat car. The engine is supplied with steam from the locomotive and pulls the plow by means of a long steel cable which is wound upon drums connected to the engine.

More recently special ballast cars have come into use for this service and now the greater part of the ballast is unloaded from these.

Fig. 105 illustrates the Hart convertible car employed for this purpose. Fig. *A* shows the car arranged for use with a plow which plows the material off through the side doors and Fig. *B* shows the car ready for center dumping or unloading the material in the center of the track. In the latter method the ballast is spread by a plow car. Fig. *C* shows the plow car in service. The diagonal shading in Fig. *B* shows the position of the ballast after being spread by the plow car when it is ready to be placed under the track by the track forces.

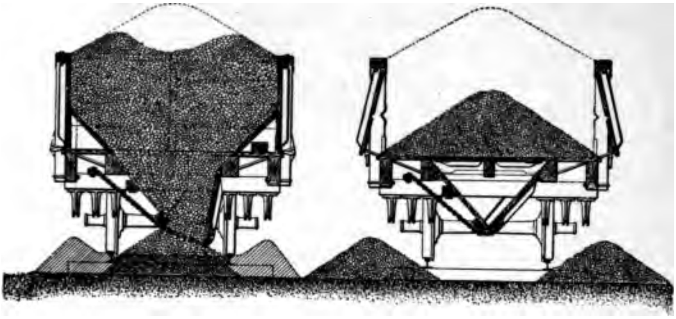
73. Distribution of Pressure through.—Considerable attention has been given to the distribution of pressure through ballast to the subgrade with a view to determining the proper depth of ballast required under different conditions.

The following experiments were made in Germany by Schubert, to determine the distribution of force upon the subgrade.*

An experimental box, 37 ins. long, 20 ins. high, and 6 ins. wide, was filled with a layer of clay 8 ins. high at the bottom, on

* See Proceedings Am. Ry. Eng. and M. of W. Assn., Vol. 7, 1906, p. 111.

top of which was placed a layer of sand 6 ins. high, and then a layer of gravel 6 ins. high, upon which a tie was laid. This tie was tamped with the ordinary tamping pick and then subjected to a load of 57 lbs. per square inch, or 8200 lbs. per



B. Center Dumping. *A*. Unloading from Sides.

C. Plow Car.

FIG. 105.—Unloading Ballast (Hart Convertable Cars).

square foot, by which the rail level was depressed. By the use of an eccentric the loading was alternately lifted from the tie and again returned, thus imitating the process of passing a loaded wheel over the track. As soon as the tie had settled

1.2 ins., which was registered upon an attached sliding plate, the tie was again raised and tamped. From time to time, photographic views and observations as to the stage or condition of the experiment were taken by removing the front wall of the experimental box. After the eleventh tamping the experiment was considered as completed, and the section then showed that a short depression (Fig. 106*A*) measuring about 12 ins. to 14 ins. wide, had been formed in the clay, with an upward swelling on each side. The pressure transmitted from the tie had accordingly distributed itself over this small width when the depth below the bottom of the tie was 12 ins.

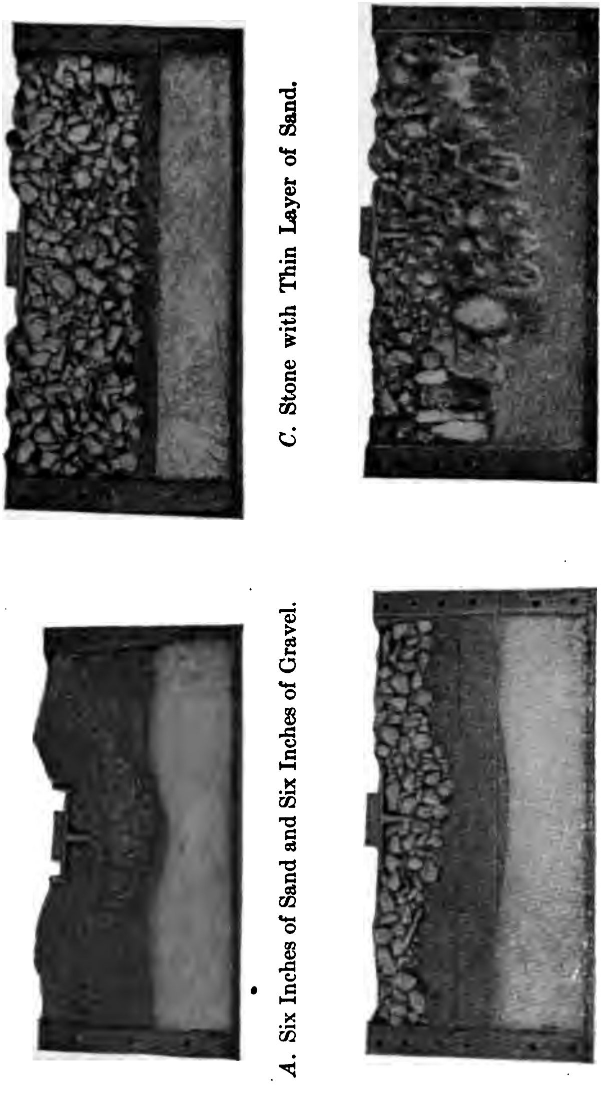
In a subsequent experiment, broken stone was used in place of gravel; otherwise the procedure was the same. From the section taken after the fifth tamping (Fig. 106*B*) a depression in the clay extending nearly over the entire width of the experimental box (27½ ins. to 29½ ins. wide) was noticeable. The distribution of the force was consequently double that of the previous experiment.

Still more favorable appeared this distribution when the height of the stone ballast is increased. In doing this, it is judicious to retain a thin layer of sand so as to prevent the larger pieces of broken stone from entering into the clay.

As will appear from the section shown in Fig. 106*C*, a depression in the clay was shown not to have taken place, and only a few of the broken stones had gone through the sand to the clay. In emptying the box only a very unimportant depression was noticeable.

Finally, the behavior of the foundation layer was investigated, and after the fourth tamping the section shown in Fig. 106*D* was taken. The stones of the foundation layer had penetrated the clay rather deeply, and not only those in the center, but also stones on the sides, from which we can conclude that the force transmitted through the tie had distributed itself nearly over the entire width of the box.

Hence, the most favorable distribution of forces is accomplished by the use of ballast of broken stone, with or without a foundation layer. The latter is, however, not suitable in a yielding sub-



A. Six Inches of Sand and Six Inches of Gravel.

B. Six Inches of Sand and Six Inches of Stone.

C. Stone with Thin Layer of Sand.

D. Stone Resting on Clay Sub-grade.

FIG. 106.—Schubert's Tests on Distribution of Pressure through Ballast.

grade, inasmuch as the stones penetrate into the grade, and the yielding soil will swell into the spaces, thus making the drainage ineffective.

The effect of overloading the subgrade and the unequal distribution of the pressure from the ties is very clearly shown in Fig. 107.

Mr. Thomas H. Johnson has made a study of Director Schubert's report with a view to deriving a formula which would

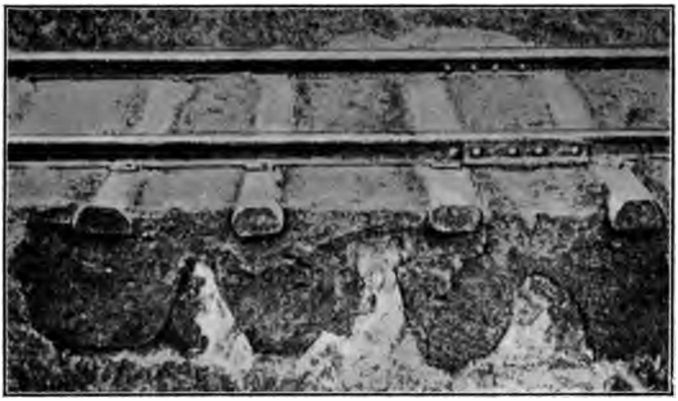


FIG. 107.—Effect of Unequal Distribution of Tie Pressure on Sub-grade. (Am. Ry. Eng. Assn. Schubert.)

show the thickness of ballast necessary to produce an equal distribution of the axle loads on the surface of the roadbed underneath the ballast.*

Referring to Fig. 108, the following formulæ are suggested by Mr. Johnson:

For gravel $x = b' + \frac{1}{2}d'$.

For stone $x = b' + d'$.

* See Proceedings Am. Ry. Eng. and M. of W. Assn., Vol. 7, 1906, p. 104.

In the figure the arcs will approximate to parabolas and may be considered as such.

The intensity of pressures is proportionate to the ordinates of the curve.

Areas of parabolic segment $=\frac{2}{3}xy$; hence mean ordinate $=\frac{2}{3}y$ or mean pressure $=\frac{2}{3}$ maximum pressure, or maximum pressure, equal to $\frac{3}{2}$ mean pressure.

Pressure at $b=0$; hence, to obtain an approximately uniform distribution over the surface of roadbed, the tie spacing S must

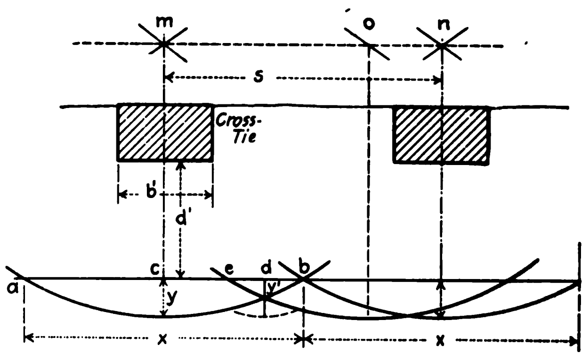


FIG. 108.—Distribution of Pressure to Sub-grade. (Johnson.)

be such that the curves overlap and have a common ordinate, $y'=\frac{1}{2}y$. This will occur when $db=\frac{1}{4}cb$ or $mo=\frac{3}{4}mn$.*

We should obviously aim to space the tie so that the area of distribution of adjacent ties will overlap and give approximately an equal distribution of the axle loads on the surface of the roadbed underneath the ballast.

With a tie spacing of 23 ins. center of ties, by applying Mr. Johnson's formulæ, we find that it will be necessary to use 45 ins. of gravel ballast and 22 ins. of stone ballast under the tie to obtain equal distribution of the subgrade.

* Approximate; to be exact, $db=0.29\ cb$ and $mo=0.71\ mn$.

Tie spacing, $S=23 \text{ ins.}=\frac{3}{4}x,$

For gravel, $S=\frac{3}{4}(b'+\frac{1}{2}d'),$

or $S=\frac{3}{4}b'+\frac{3}{8}d',$

$\frac{3}{8}d'=S-\frac{3}{4}b',$

and $d=\frac{8}{3}(S-\frac{3}{4}b')=\frac{8}{3}(23''-\frac{3}{4}\times 8'')=45\frac{1}{3} \text{ in.}$

For stone $S=\frac{3}{4}(b'+d'),$

or $S=\frac{3}{4}b'+\frac{3}{4}d',$

and $d'=\frac{4}{3}(S-\frac{3}{4}b')=\frac{4}{3}(23''-\frac{3}{4}\times 8'')=22\frac{2}{3} \text{ in.}$

The road department of the Pennsylvania Railroad has installed an interesting piece of apparatus on the grounds of the South Altoona foundry to test the bearing qualities of different kinds of roadway and ballast. The particular ballast or subgrade to be tested is placed in three heavy boxes that extend across the track and have sufficient depth to serve the purpose. The track crosses this on a level and extends out on either side, terminating in a short and sharp incline. A four-wheel car on this track is loaded with pig metal to obtain any desired weight on the wheels. This car is also equipped with electric motors. A shed built across the track carries an overhead rail, from which a motor current is obtained, through a contact shoe on the car.

When current is turned on, the car moves out to the end of the conductor rail, and here, as the contact is broken, the power of the motor is shut off. The car runs on until stopped by the adverse grade, and meanwhile a trip reverses the current connections to the motor. Stopped by the grade, the car runs back beneath the current rail, when its motor drives it to the other end, where the movement is again reversed. In this way the car is made to travel back and forth automatically over the track until the desired results are obtained, the number of trips being automatically registered upon a counter.*

* See Proceedings Am. Ry. Eng. Assn., Vol. 13, 1912, pp. 113–265; and Railway Age Gazette, June 11, 1909, and July 21, 1911.

These tests are the most extensive of the kind ever conducted in this country. It was felt that while the data obtained by Director Schubert were very instructive, yet more valuable data could be obtained from a series of experiments if made in a manner more nearly approaching actual track conditions.

The track was 109 ft. in length, built of new P. R.R. standard 85-lb. rail with 7-in. by 9-in. by 8½-ft. ties spaced 25½ ins. center to center. It being impracticable to run the car faster than about 5 miles per hour, at which speed any effect upon the track, due to impact alone would be negligible, a weight of 75,000 lbs. per axle was chosen for the experimental truck.

A series of five tests was completed, the first one beginning on Sept. 2, 1908, and the last one ending on Aug. 2, 1910. Table IX gives general data of the tests and Fig. 109 illustrates some of the sections obtained. Water was applied by sprinkling the boxes to observe the effect of moisture on the ballast; the amount applied in each test is shown in the table by inches of rainfall.

In test No. 1 the line of demarkation between the bottom of the ballast and the roadbed material was not straight. The test showed conclusively that a depth of 8 ins. of trap-rock ballast, when laid on the usual roadbed material, was not sufficient to distribute the weight carried by the ties uniformly over the roadbed.

The results in the third box showed, however, that if 12 ins. of permeable material, such as cinder, were used beneath the 8 ins. of ballast, the distribution of the weight over the roadbed material was much better.

The results of the first test led to the second test to determine how a depth of 12 ins., 18 ins. and 24 ins. of trap rock under the ties would behave. In test No. 2 the dividing line between the ballast and the loam was quite straight in box No. 3, but in boxes Nos. 1 and 2 there existed some depressions in the line especially under the rail.

A study of the sections in test No. 3 showed that the loam was more evenly depressed in box No. 3 than in the other boxes where stone had been substituted for part of the cinder during the test.

Test No. 4 showed that the gravel and slag distributed the pressure upon the loam with about the same efficiency.

Test No. 5 was made to determine whether a combination of rock and cinder would prove as satisfactory as the rock alone.

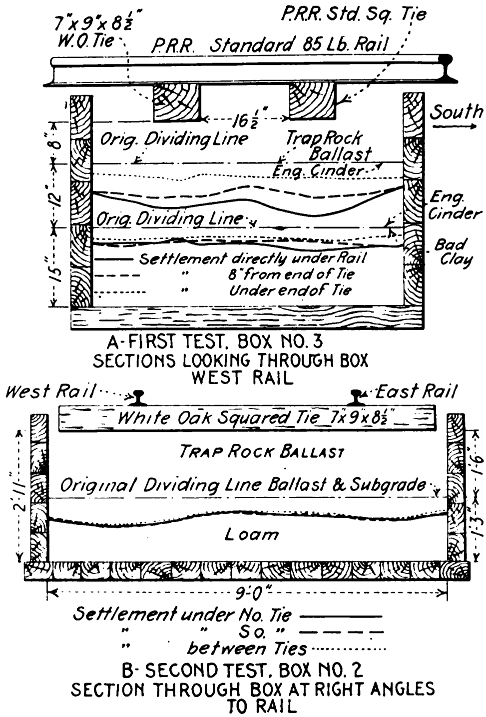


FIG. 109.—Altoona Tests on Distribution of Pressure through Ballast.

It was found, however, that the line between the ballast and the loam in box No. 3 was not as good as in box No. 3 of Test No. 2.

The results obtained from these tests are apparently consistent with those derived from Johnson's formula.

A distinct arching effect has been observed in static tests on

TABLE IX

Summary of Roadbed Tests at Altoona

Test No.	1	2	3		4		5	
			1st Part.	2d Part.	1st Part.	2d Part.	1st Part.	2d Part.
From to	Sept, 2, 1908 Jan. 5, 1909	Apr. 18, 1909 June 15, 1909	June 28, 1909 July 20, 1909	July 21, 1909 Aug. 6, 1909	Oct. 19, 1909 Nov. 17, 1909	Nov. 17, 1909 Dec. 3, 1909	May 19, 1910 June 24, 1910	June 24, 1910 Aug. 2, 1910
Material in Box No. 1	8″ trap rock 27″ bad clay	12″ trap rock 26″ loam	24″ cinder 12″ loam	Removed 8″ cinder from top and replaced with trap rock.	24″ slag 12″ sandy loam	8″ slag removed and 8″ trap rock added	24″ cinder 13″ sandy loam	6″ cinder removed and 6″ trap rock added
Box No. 2	8″ trap rock 27″ sandy loam	18″ trap rock 19″ loam	24″ cinder 12″ loam	Removed 12″ cinder from top and replaced with trap rock	24″ slag 12″ sandy loam	12″ slag removed and 12″ trap rock added	24″ cinder 13″ sandy loam	8″ cinder removed and 8″ trap rock added
Box No. 3	8″ trap rock 12″ cinder 15″ bad clay	24″ trap rock 14″ loam	24″ cinder 12″ loam	Unchanged	24″ sandy gravel 12″ sandy loam	12″ gravel removed and 12″ trap rock added	24″ cinder 13″ sandy loam	10″ cinder removed and 10″ trap rock added
No. of round trips......	81,600	49,932	45,500	40,100	45,561	40,060	19,210	93,094
Settlement:								
Box No. 1	$10\frac{3}{16}$″	$8\frac{1}{4}$″	$8\frac{1}{4}$″	$2\frac{3}{4}$″	$12\frac{1}{4}$″	$4\frac{1}{4}$″	$2\frac{3}{4}$″	$5\frac{1}{4}$″
Box No. 2	$14\frac{1}{16}$″	$9\frac{1}{4}$″	$8\frac{1}{4}$″	$2\frac{1}{4}$″	$13\frac{1}{4}$″	$4\frac{1}{4}$″	$2\frac{1}{4}$″	$5\frac{1}{16}$″
Box No. 3	$10\frac{1}{4}$″	$9\frac{1}{4}$″	$7\frac{1}{4}$″	$2\frac{1}{4}$″	$8\frac{1}{4}$″	$2\frac{1}{4}$″	$2\frac{1}{4}$″	$4\frac{1}{4}$″
Rainfall.....	$98\frac{1}{4}$″	$11\frac{1}{4}$″	$8\frac{1}{4}$″	7″	8″	6″	$4\frac{1}{2}$″	14″

the distribution of pressure through gravel; but under dynamic loading where the material is subjected to shocks this would seem to be absent and the greatest intensity of pressure occurs immediately under the point of application of load.

Fig. 110 illustrates the distribution of pressure in dry sand as determined by Moyer.* The sudden bends in these curves which occur as the eccentricity of the load increases for depths of sand less than 12 ins. in Fig. *A* and 24 ins. in Fig. B appear to indicate a certain critical depth for different pressures that would be

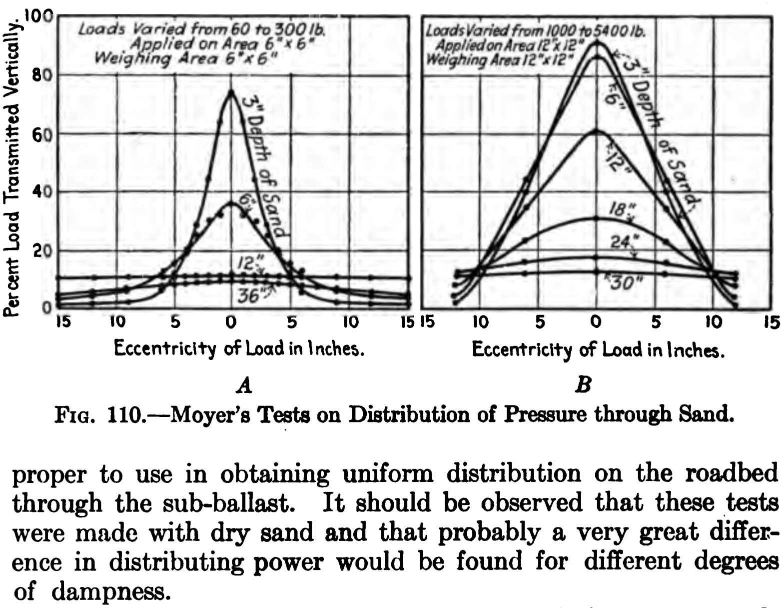


FIG. 110.—Moyer's Tests on Distribution of Pressure through Sand.

proper to use in obtaining uniform distribution on the roadbed through the sub-ballast. It should be observed that these tests were made with dry sand and that probably a very great difference in distributing power would be found for different degrees of dampness.

The American Railway Engineering Association recommends the following for the proper depth of ballast.†

From the data available, it is concluded that with ties 7 in. by 9 in. by $8\frac{1}{2}$ ft., spaced approximately 24 in. to 25.5 in., center to center, a depth

* Engineering Record, May 30, 1914, p. 608.
† Supplement to Manual, 1912, p. 7.

of 24 in. of stone ballast is necessary to produce uniform pressure on the subgrade, and a combination of a lower layer of gravel or cinder ballast (18 in. to 24 in.) and an upper layer of stone ballast (6 in. to 10 in.) approximately 24 in. deep in the aggregate, with the same spacing of the ties, will produce nearly the same results.

The depth of the ballast refers to the distance from the bottom of the tie to the top of the subgrade.

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CHAPTER IX

MAINTAINING TRACK AND RIGHT OF WAY

74. Track Laying.—In relaying rail, that is, taking it up from main lines and laying it on branches, the rails are frequently battered and worn at the ends, and the practice is quite general to saw off enough of the end to get rid of the bad metal and then redrill the rails for the splice. A rail saw is located at some convenient point on the road and as the rail is taken up it is shipped to the saw, the ends sawed off and the rail sent to the part of the road where it is to be relayed.

In laying rail on an existing line the steel is distributed alongside of the track at the ends of the ties by a work train. The rails are then laid on the ties, outside of the rails in the track, and bolted together in sections of about ten rail lengths. Between the passage of trains the old rails are thrown out and the new section thrown in and the ends connected up. As the new section is not, as a rule, of exactly the same length as the old, a switch point is used for the connection; this connection should not, however, be left overnight, but a rail should be cut and drilled so a regular connection with angle bars may be made.

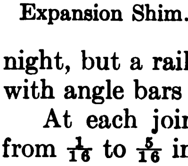


FIG. 111.
Expansion Shim.

At each joint in the rails an opening must be left varying from $\frac{1}{16}$ to $\frac{5}{16}$ in. This is accomplished by means of "expansion shims." Fig. 111 illustrates a cast-iron shim used for this purpose.

Table X gives the temperature expansion for laying rails recommended by the American Railway Engineering Association.*

* Manual, 1911, p. 86.

TABLE X

TEMPERATURE EXPANSION FOR LAYING 33 FT. RAILS (AM. RY. ENG. ASSN.)

Temperature (taken on rail) (Fahrenheit).	Opening between rails.
$-20°$ to $0°$	$\frac{5}{16}$ in.
0 to 25	$\frac{1}{4}$ in.
25 to 50	$\frac{3}{16}$ in.
50 to 75	$\frac{1}{8}$ in.
75 to 100	$\frac{1}{16}$ in.

Over 100° the rails should be laid close without bumping.

The procedure on new track is quite different; here if the work is of any magnitude a track-laying machine is generally used. This consists of a flat car equipped with beams extending ahead of the car upon which a small dummy car containing ties may be run and dumped. These ties are spaced by the track-laying gang and two rails are dropped in place from the beams ahead of the car. These are connected up and spiked to the ties and the whole train moves ahead one rail length and the operation is repeated.

Where the country is flat and the line is accessible to teams the ties may be distributed on the grade by teams and the rails and other track material brought up by train. In this case a track-laying machine is not necessary, as the rails can be unloaded from the sides of the flat car, which is placed ahead of the engine, and carried forward by the men, the train moving ahead a rail length at a time as the track is built.

Where an American ditcher machine is available the work of of track laying can be facilitated by its use. The arrangement of the train should be as shown in Fig. 112. The machine is mounted on a flat car which is placed at the head of the material cars.

A car of steel (80 to 100 rails to the car) is placed next to the car on which the machine stands, and behind the steel are two cars of ties. The locomotive spots the train as the track is laid, and brings in additional material.

The ties are arranged in piles of 18 or 20, sufficient to lay one 33-ft. panel of track. A chain is hooked around the ties, which are dragged over the tops of the cars, or along the sides of the cars on the grade, to where a straight lift can be obtained, then swung around and dropped into place on the grade. Two men on tie cars keep the ties piled up ready for the machine to take away. The tong runner hooks tongs on the rail, and passes the chain back to men on the tie cars. The machine then swings around, picks up a rail, and slewing around to the front, deposits it on the grade.

Fig. 112.—Laying Track with American Ditcher.

Spikes, bolts and angle bars are carried on the car with the machine.

With the heavy loads and dense traffic of recent years it has been found necessary to use a closer spacing of the ties than was formerly employed in order to give the rail as much support as possible and obtain a uniform distribution of the load to the subgrade.

While the spacing varies somewhat on different roads, it is generally considered good practice to use a tie spacing which will support the rail for 45 per cent of its length. This appears to be about the minimum spacing which will leave room between the ties for the proper use of the tamping tool.

In relaying rails it was formerly the universal practice to respace the ties at the joints so as to maintain a symmetrical bearing. This has been looked upon as very important, and the labor of spacing the joint ties constitutes a considerable part of the cost of relaying rail. The joints are slotted to receive the spikes and prevent the rail moving relatively to these ties. Within the last few years several roads, among which are the Pennsylvania Lines, Pittsburgh and Lake Erie, and the Chicago, Milwaukee and St. Paul, have used more or less extensively joints with no slots to spike through and in relaying rail make no attempt to space the joint ties. It is claimed a substantial saving in maintenance is effected due to not disturbing the bed of the tie in addition to the reduced cost when the rail is relaid. If it is necessary to prevent the movement of the rail, anti-creepers are put on at the quarter or eighth points of the rail.

75. Surfacing.—Unless a general lift of the track is to be made the track surfaced should not be lifted out of its bed, but only the low places brought up to conform to the higher.

When not surfacing out of face, as in case of picking up low joints or other low places, the general level of the track should not be disturbed. Where the rails are out of level, but where the difference in elevation is not excessive and is uniform over long stretches of track, a difference in elevation between the two rails of three-eighths in. may be allowed to continue until such time as the track would ordinarily be surfaced out of face.

In tamping broken-stone ballast, it is customary to tamp from a point 15 ins. inside of the rail to the end of the tie, tamping the end of the tie outside the rail first, starting well under the rail. When practicable, a train is allowed to pass over the track before tamping inside the rail. The center of the tie should not be tamped, but the ballast should be filled in between the ties to the top of the tie at the center, and sloped from this point to conform to the standard section.

The same procedure is used for gravel, sand or cinder ballast, except that the tie is shovel packed lightly at the center.

If the tie is tamped too much at the center, the track becomes "center bound," that is, the ties have a tendency toward an unstable bearing on the ballast.

That this principle has been known for a long time is shown by the following statement, made by Huntington over thirty years ago.*

> It is customary to tamp the ties their entire length; but it is found to be bad practice to tamp as hard midway between the rails as at the ends of the ties and on the inner side of the rails. All track newly raised will settle more or less, and if the middle of the track is tamped hard it will cause it to rock and work out of line, as ballast will wash out from under the ends of ties when it remains hard and full in the center. Such track will rock from side to side in a very disagreeable manner.

Fig. 113, showing the form the tie takes under load, is derived from an elaborate series of tests on the action of the tie in the ballast made by M. Cuënot.† This makes it clear why the tamping should be lightly done at the center both from the standpoint of obtaining a more stable track and also to avoid unduly stressing the tie by causing too great a bending movement at the center.

In stone ballast the tamping is usually done with a tamping pick or bar, while in gravel ballast the shovel is more generally employed.

The question of tamping the ballast under the tie is of considerable importance, and the labor required to keep the ties properly tamped constitutes one of the largest single items of track maintenance. During the passage of a train the tie is depressed in the ballast. Most of the depression is elastic, but the tie is given a certain amount of permanent depression by every train which passes over it. This permanent displacement augments in time until the track is no longer in a condition to

* The Road-Master's Assistant and Section Master's Guide, by W. S. Huntington, revised by Chas. Latimer, 1884, The Railroad Gazette, New York, p. 47.

† Deformations of Railroad Tracks, 1907. The Railroad Gazette, New York.

afford smooth riding of the trains and it is necessary to tamp the ballast to restore the good riding qualities of the track.

Fig. 114 illustrates some of the results of tests on the tracks of the Pennsylvania Railroad made by the Government in 1894 and 1895.

The depression of rails was measured by means of a sensitive level bubble, mounted on a rod, carrying at one end a screw micrometer, which rested on a stake driven in the road-bed 30 ins. from the rail; the other end of the rod rested upon the base of the rail. The depression of the track was thus measured with reference to the top of the stake used as a bench mark.

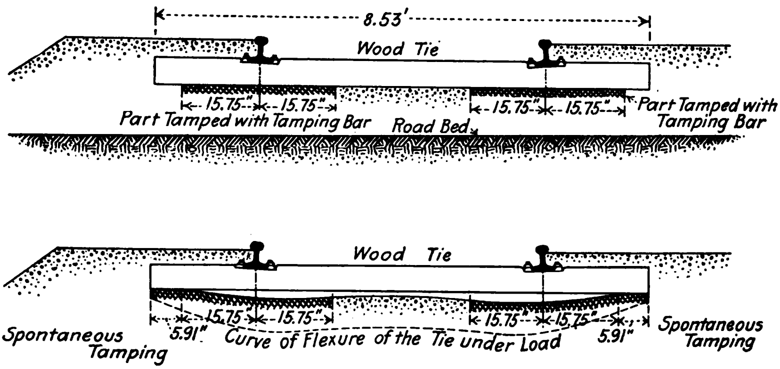


FIG. 113.—Cuënot's Tests on Distribution of Tamping under Tie.

The depression of the rails examined shows, with the 60-lb. rails, the least depression on the gravel ballast, the order of rigidity being gravel, stone and cinder ballast. With the 70-lb. sections, the order of rigidity is gravel, cinder and stone ballast. Under 85-lb. rails, the stone ballast gave greater rigidity than the gravel. No test for depression was made with cinder ballast under 85-lb. rails, and only stone ballast was used under 100-lb. rails.

Table XI states the mean depression of the driving wheels, and also the mean depression of all the other wheels of the locomotive in each experiment. There is in the table a column

of differences which states the excess of depression of the drivers over that of the other wheels. The column of differences is

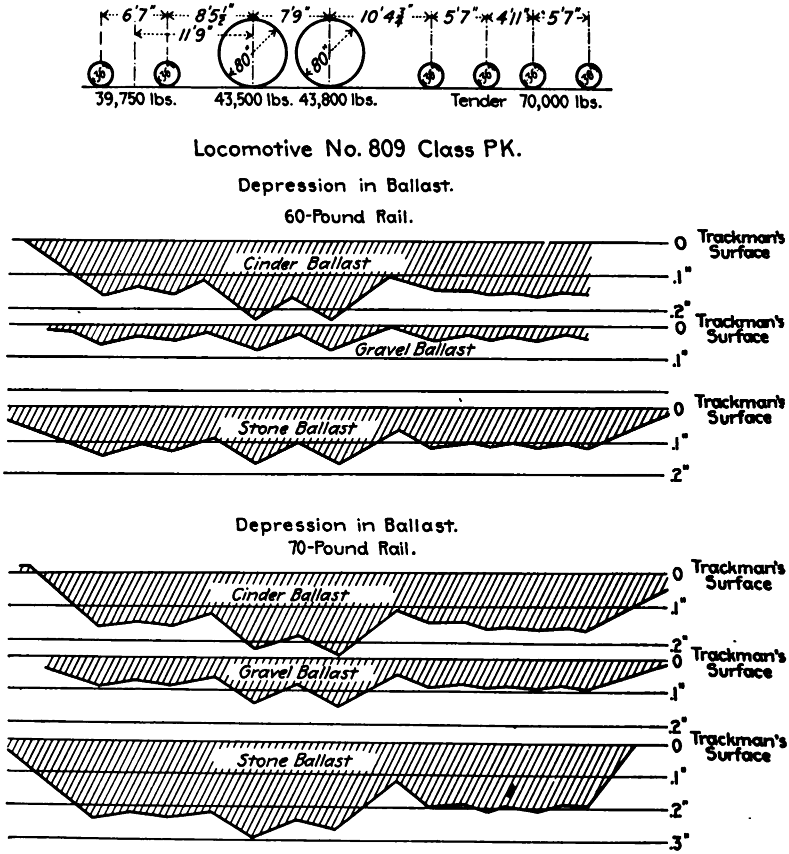


FIG. 114.—Depression of Ballast, Government Rail Tests.

useful in showing the additional depression of the rails under the weights of the driving wheels after they have been loaded by the other wheels.

Under the 60- and 70-lb. sections, the gravel ballast gave the greatest rigidity under the drivers, as well as under the other wheels, and in the column of differences the excess of depression was least for this kind of ballast.

The total depression with 85-lb. rails was less for the stone than for the gravel ballast, although the excess of depression under the drivers was practically the same in the two cases.

The depression of the rails on frozen gravel ballast, in which there was no visible movement of the ties, would seem to represent about the attainable limit of rigidity in track on wooden ties.

TABLE XI

DEPRESSION OF RAILS—MEAN DEPRESSION UNDER DRIVING WHEELS AND MEAN DEPRESSION UNDER PILOT AND TENDER WHEELS

GOVERNMENT RAIL TESTS

(House Documents, Vol. 46, 54th Congress, 1st Session, 1895–96. No. 54, Tests of Metals.)

Rail Weight per Yd.	Ballast.	Locomotive.	Drivers.	Pilot and Tender.	Difference.
(Pounds)			Inch	Inch	Inch
60	Cinder	Passenger No. 809.	.229	.154	.075
60	Gravel	Passenger No. 809.	.073	.042	.031
60	Stone	Passenger No. 809.	.162	.122	.040
70	Cinder	Passenger No. 809.	.230	.157	.073
70	Gravel	Passenger No. 809.	.138	.089	.049
70	Stone	Passenger No. 809.	.277	.207	.070
85	Gravel	Passenger No. 809.	.233	.184	.049
85	Stone	Passenger No. 809.	.144	.097	.047
100	Stone	Passenger No. 809.	.168	.116	.052
95	Gravel, frozen, rail No. 1	Passenger No. 209.	.139	.103	.036

For weights of engine 809, see Fig. 114.

Engine 209 had a total weight of 199,700 lbs., as follows:

Engine pilot........................40,700 lbs.
Drivers..............................75,000 lbs.
Tender...............................84,000 lbs.

A very critical examination led to the conclusion that each passage of a locomotive left the rail in a slightly different state than it before occupied, and that some sluggishness of recovery in the ballast had an influence on these minute displacements.

Dr. P. H. Dudley gives from 0.2 in. to 0.4 in. as the amount the general running surface of the rail is below the trackmen's surface. Director Schubert states that a wooden tie is depressed from 0.3 in. to 0.4 in. before it reaches a solid bearing. M. Coüard observed that the maximum depression of the tie was about 0.12, and states that the amount of depression is not proportional to the load.

M. Cuënot's tests showed that a depression is left under the tie of about 0.04 in. and the loaded tie is depressed about 0.12 in.

The relation of the bearing power of the tie to the amount it is depressed in the ballast is not thoroughly understood.

Cuënot states that:*

The German engineers Weber, Winckler, and Zimmermann have advanced the theory that the pressure, P, of the ballast per unit of surface of the cross-tie which it supports is, at each point in direct ratio with the sinking, Y, of the latter; or $P=CY$, when C is a coefficient depending upon the character of the ballast. The researches of these engineers may be summed up as follows:

(*a*) The results of experiments are stated to agree quite closely with the supposition that the pressure on the unit of surface is in direct proportion with the measure of the sinking.

(*b*) With a subsoil supposed to be good, the magnitude of the coefficient of ballast has been found: for gravel ballast (without metaled bed) $C=3$; for gravel ballast (with metaled bed) $C=8$; for ballast of small stones and scoræ $C=5$.†

(*c*) The sinking observed under a load in motion, at speeds varying from 40 to 60 kilometers (24.85 to 37.28 miles) per hour, was not much greater than the sinking observed under the same load in a state of repose.

It appears that under the tie at the rail a depression in the ballast is formed, and that even under a comparatively

* Deformations of Railroad Tracks, 1907. The Railroad Gazette, New York.

† P in kilograms per square centimeter; Y in centimeters.

light pressure the tie deflects to the depth of this depression. This would seem to represent most of the elastic depression, and indicate that there is a sort of spontaneous tamping of the ballast by the tie near the rail bearing which eventually results in the permanent displacement of the ballast, and consequent rough riding of the track.

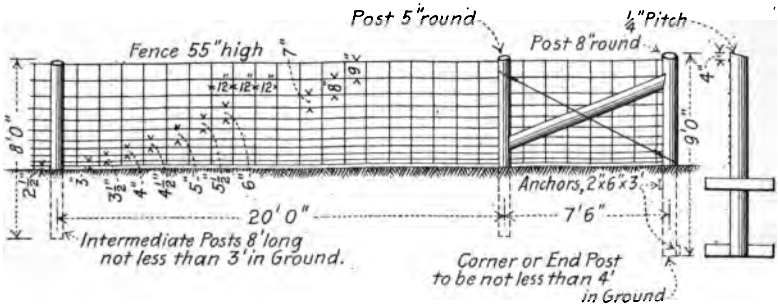


Fig. 115.—Woven Wire Right of Way Fence. (Standard recommended by the New York Central Lines Maint. of Way Committee.)

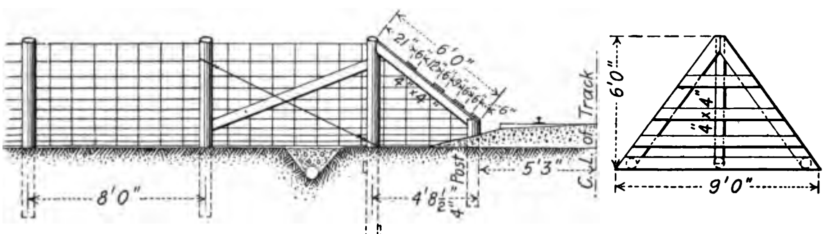


Fig. 116.—Wing Fence and Apron. (Standard recommended by the New York Central Lines Maint. of Way Committee.)

76. Right-of-way Fences.—The general arrangement of the woven wire right-of-way fence is shown on the plan recommended by the New York Central Lines Maintenance of Way Committee given in Fig. 115. The wing fence shown on the plan in Fig. 116 is used at highway crossings in connection with the cattle guards which will be described later.

The right-of-way fence shown consists of eleven longitudinal steel wires; the top and bottom wires are No. 7 gauge and the intermediate and stay wires are No. 9 gauge. Many engineers prefer to use the same size wire for all the line wires and the stays as they think that the fence can then be stretched more uniformly without danger of exceeding the strength of the smaller line wires. The majority of railway specifications at the present time call for all No. 9 stay and line wires, although formerly No. 9 line and No. 11 stay or No. 9 top and bottom with No. 11 fillers and stay wires was quite the general practice.

The wires should have an elastic limit of at least 1500 lbs. for the No. 9 gauge and 2000 lbs. for the No. 7 gauge wire, with an ultimate strength of 1800 lbs. and 2500 lbs. respectively.

About 80 per cent of all the fence wire is made by the acid Bessemer process. The Pittsburgh Steel Company's fence is, however, made of open-hearth steel, which, according to the manufacturers, has the following composition:

	Per Cent
Carbon	0.08 to 0.10
Phosphorus	0.02 to 0.04
Sulphur	0.03 to 0.04
Silicon	0.20
Manganese	0.40

The elastic limit is about 43,000 lbs. per square inch with an ultimate strength of from 72,000 to 75,000 lbs. per square inch, the high strength for this chemical composition being due to the wire drawing of the steel during manufacture, which adds 7000 to 8000 lbs. to the tensile strength. This fence has electrically welded joints, which on account of the wire saved at the joints makes it cost somewhat less than the fence where the intersections of the longitudinal and stay wires are not welded.

In specifying wire for fence the phosphorus should not exceed .08 per cent. It is desirable probably to keep the manganese low, as the tests at the Carnegie Institute, Pittsburgh, appeared to show that if the manganese was kept below .50 per cent a more rust-resisting fence was had than in the case of higher

manganese. The carbon rarely runs above .12 per cent and the tensile strength is obtained, as previously explained, by wire drawing.

Right-of-way fence is nearly always purchased already woven, but where the roughness of the ground renders impracticable the proper stretching or economical erection of the woven-wire fence, the fence is erected in the field.

The wire of the right-of-way fence is generally protected from corrosion by being galvanized.

Experiments have been made with Sherardizing the wire.

The Sherardizing process consists of the amalgamation of oxide of zinc with iron at a certain temperature, which results in a protective alloy surrounding the wire instead of the coating on the galvanized wire. Sherardizing seems to give a very desirable product, but it is quite expensive as compared to the hot galvanizing process. The ordinary process of galvanizing is to dip the fence before weaving. When the fence is galvanized after weaving a more rust-resisting fence seems to be the result.

The best material for wooden fence posts is probably locust, on account of the long life of this timber. Satisfactory fence posts are, however, each year more difficult to secure. Substitutes, such as reinforced concrete and iron, are quite expensive and the use of cheaper woods treated to prevent decay is beginning to attract attention.*

The more expensive kinds of wood, such as locust, white oak and cedar, which have long been used for posts, are now too scarce and too much in demand for other uses to allow of their meeting the demand for posts. Fortunately most of the so-called "inferior" woods are well adapted to preservative treatment. This is especially true of the cottonwoods, aspens, willows, sycamore, low-grade pines and oaks and some of the gums. When properly treated these woods will outlast the best grades of untreated timber, and are therefore cheaper and more satisfactory.

It is well known that wood decays first where it comes in con-

* See discussion of fence posts in Forest Service, Circular No. 117, from which the following data relative to wooden posts have been taken.

tact with the ground. This is because the fungi, which cause decay, find there the conditions most favorable for their growth. Protection is, therefore, most needed at this point. When wood is fully exposed to the air as in the top of posts, the moisture is rapidly evaporated and decay is very slow.

A number of more or less crude methods have been tried for prolonging the life of fence posts. They have brought out certain points which may prove of value if more efficient treatment cannot be undertaken. Chief of these are the following:

A seasoned post is better than a green post; hence posts should be as dry as possible before being set.

Setting a post small end down does not check its decay.

By piling stones around the base of the post or setting it in masonry or concrete, vegetation is kept away, better drainage is secured, and the post is kept drier. The slight gain thus secured does not, however, justify the cost.

Charring the butt of the post, if properly done, gives good results. Only dry posts should be charred, and the charred surface should extend at least 6 ins. above the ground line.

If the butt of a post is painted with or plunged into a hot solution of carbolineum or creosote very good results can be obtained. Next to a regular treatment, this method is doubtless the best.

Apart from the question of decay, many posts in railway fences are destroyed by ground fires. This reason is an important consideration in comparing the concrete with the treated wood post for railway purposes.

Concrete makes a practical, durable and economical fence post. The posts should be 8 ft. long and preferably of the same cross-section, and spaced the same distance apart as is usual for wood posts. The poured posts appear to have considerably greater strength than those in which the mixture is tamped. To obtain the best results posts should be allowed to cure for about two months before being used.

The proper placing of the reinforcement is one of the greatest problems in successful post manufacture. Table XII shows the amount of reinforcing metal required to develop the compressive

strength of the concrete. The reinforcement should be placed in the corners of square or rectangular posts and from $\frac{1}{2}$ to $\frac{3}{4}$ in. in from either side.

TABLE XII

REINFORCEMENT IN CONCRETE FENCE POSTS

(The Farm Cement News)

Dimensions.			Volume of Post in Cu.ft.	Weight of Post in Pounds.	Amount of Reinforcing Metal Required.
Length.	Top.	Bottom.			
6′ 6″	3″×3″	5″×5″	.72	100.8	Four
7 0	3 ×3	5 ×5	.78	109.2	$\frac{1}{4}$″
7 6	3 ×3	5 ×5	.83	116.6	Round
8 0	3 ×3	5 ×5	.89	124.6	Rods
6 6	4 ×4	5 ×5	.91	127.4	Four
7 0	4 ×4	5 ×5	.98	137.2	$\frac{5}{16}$″
7 6	4 ×4	5 ×5	1.05	147.0	Round
8 0	4 ×4	5 ×5	1.12	156.8	Rods
6 6	5 ×5	6 ×6	1.36	191.1	Four
7 0	5 ×5	6 ×6	1.47	205.8	$\frac{3}{8}$″
7 6	5 ×5	6 ×6	1.57	220.5	Round
8 0	5 ×5	6 ×6	1.68	235.2	Rods

Fig. 117 shows an English fence used for railway purposes.* The straining post shown is suitable for the commencement or end of a line of fencing. Wires of from $\frac{3}{16}$ to $\frac{5}{16}$ in. in diameter are used to reinforce these posts, four of the larger size being used for the straining and main posts and the smaller size for the "prick" posts, bound together at intervals with wires of about $\frac{1}{8}$ in. in diameter.

Cattle guards are placed at all road crossings to prevent cattle getting on the right of way. The earliest form of cattle guard was the old pit guard, which was a positive bar to the cattle. The greatest difficulty with this guard was due to the fact that

* Reinforced Concrete Railway Structures, J. D. W. Ball, 1914. D. Van Nostrand Co., New York, p. 195.

leaves and other rubbish would collect in the pit and cause fires which would endanger the track over the pit. Moreover, the guard may hold fast on the track a frightened animal with broken or entangled legs. A modified type of pit guard is shown in Fig. 118*A*, consisting essentially of deep cross-ties so spaced in proportion to their depth as to afford no knee room for an animal in taking a step.

The guards used at the present time generally consist of surface guards of slats of wood, tile or metal laid on edge and

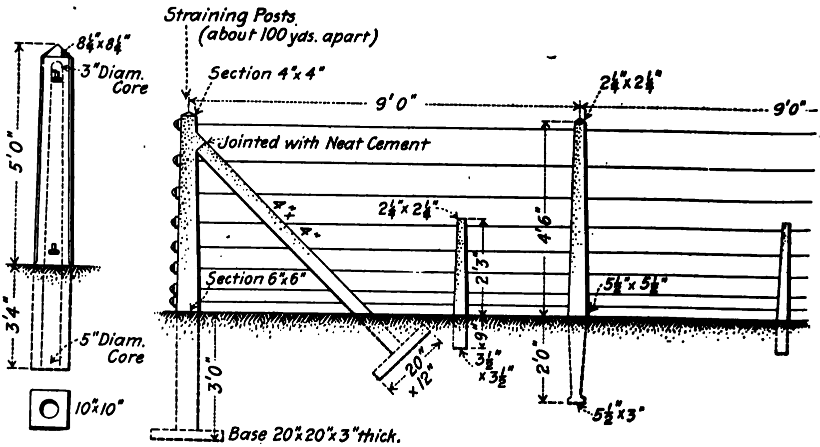


FIG. 117.—Reinforced Concrete Fence Posts. (Ball.)

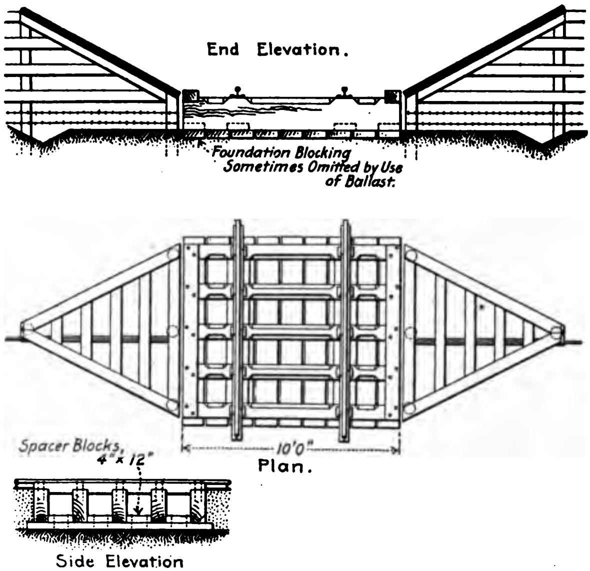
which the cattle find more or less difficulty in passing over. (See Fig. 118*B*.) None of the guards present the same positive bar to the passage of stock as the old pit guard.

77. Snow and Sand Fences and Snow Sheds.—Snow fences are very often built in portable sections from 12 to 16 ft. long and placed in the fields adjacent to the track on the approach of winter and removed in the spring to permit the ground to be cultivated. Tree planting is also sometimes done to protect the track, as on the Great Northern Railway in eastern Montana, North Dakota and Minnesota. Where there is much drifting

of sand, a light fence of lath and wire may be used with good results.

The American Railway Engineering Association recommends the following in reference to snow fences and sheds:*

The character of the snow fence and its location for the protection of a given point depends largely upon local conditions, some of which can



A. Modified Type of Pit Guard.

Fig. 118.—Cattle Guards. (Am. Ry. B. & B. Assn.)

only be determined by experiment, and for this purpose portable snow fence is recommended.

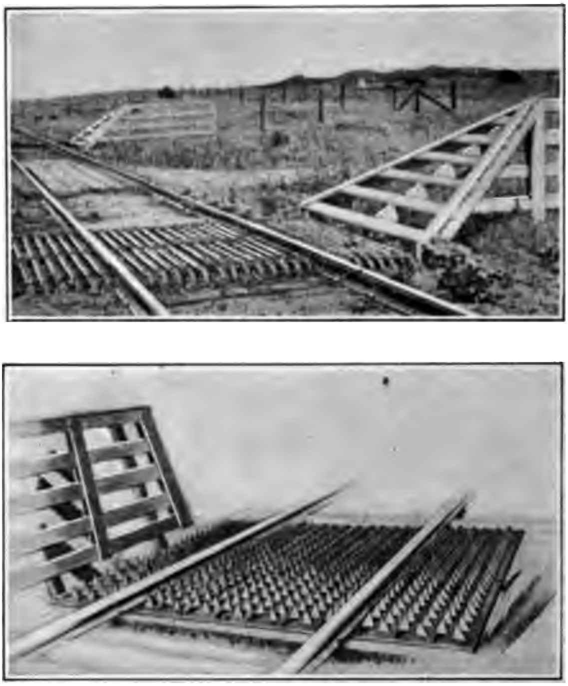
Where local conditions permit, a permanent snow fence located on the right-of-way line is most economical.

Where permanent wooden fences are used, the boards should be laid close, where the right of way is 50 ft. or less from the center of the track; for greater distances, space should be provided between the

* Manual, 1911, p. 211.

boards, and at 100 ft. distance, 50 per cent of the fence should be open space.

The height of permanent board fence depends upon the probable amount of snow. The maximum height, however, should be 10 ft.



B. Types of Surface Guards.

FIG. 118.—Cattle Guards. (Am. Ry. B. & B. Assn.)

Snow sheds are expensive to construct and expensive to maintain, and the railway should be so located, if possible, as to make their construction unnecessary. Their use should be confined to localities which require protection from mountain snow-slides, and they should be constructed of permanent material.

Keeping the switches and interlocking apparatus free from snow is a large item of expense, on roads located in northern climates, when done with brooms and shovels. The most efficient method of removing snow and ice from the switches in large yards and at terminals is by the use of a burner which melts the snow. However, when there is a heavy fall it is necessary to remove at least a part of the snow with shovels.

Light falls of snow may be cleared from the track by the use of flangers. These are suitable only when the depth is less than 6 ins. over the top of the rail, and in those parts of the country exposed to heavy falls of snow, plows are necessary to keep the lines open for traffic.

Push or wedge plows may be used up to 5 or 6 ft., but in heavy or long drifts and in hard-packed icy snow, it is necessary to use the rotary.

This plow, shown in Fig. 119, consists of a boiler and engine for operating the cutting wheel. The wheel is composed of ten hollow cone-shaped scoops, the surfaces of which are perfectly smooth so that it is impossible for the snow to stick in any way. The plow is pushed ahead of a powerful engine, and enters the snow bank at a speed of 3 or 4 miles per hour.

The wheel before entering the bank is revolving about 150 revolutions per minute and when about 5 ft. from the bank the speed of the wheel is increased.

On the Northern Pacific the rotary plow in raising the great blockade during the winter of 1887–1888 successfully removed the snow in drifts which were in some cases three or four times the height of the plow.

78. Crossings.—Crossings in unpaved streets and highways are made of plank. A flangeway is generally provided by placing a rail on its side so that the head of the rail comes next to the web of the running rail, and the flange forms a support for the edge of the crossing plank. Where much travel passes over the crossing it should be full planked between the rails, but in unimportant crossings single planks may be used next the rails and the space between the planks filled with gravel, crushed stone or screenings.

For important crossings on paved streets with heavy traffic, the Committee on Signs, Fences and Crossings of the American Railway Engineering Association recommends the following:*

A. American Locomotive Co. Plow.

B. Plow without Housing.

C. Rotary at Work on a Heavy Grade in Deep Snow.

FIG. 119.—Rotary Snow Plow.

(1) Treated ties should be used, laid on a bed of crushed rock, gravel or other suitable material, not less than 8 in. in depth, placed in about 3-in. layers, each to be thoroughly rammed to compact it.

* Proceedings, Vol. 16, 1915, p. 443.

(2) Vitrified tile drains not less than 6 in. in diameter, with open joints, leading to nearest point from which efficient drainage may be obtained, or with sufficient outlets to reach sewers or drainage basins, should be laid on either side of and between tracks, parallel with ballast line and outside of ties.

(3) One hundred and forty-one lb., 9-in. depth girder rail, or similar section, with suitable tie-plates and screw-spikes, should be used. Tracks should be filled in with crushed rock, gravel or other suitable material, allowing for 2-in. cushion of sand under finished pavement.

(4) Ballast should be thoroughly rammed as it is installed to prevent settlement of paving foundations. Two inches of good sharp sand should be placed on top of ballast.

(5) Paving must conform to municipal requirements, granite or trap rock blocks preferred. Hot tar and gravel should be poured into the joints as a binder.

The protection of crossings with considerable traffic is an important matter. In most large cities programs are being carried out for the elimination of all street crossings at grade. In small towns, however, there are many crossings where on account of the expense involved this is not practicable, and such crossings are protected by a watchman, and, if much traveled, by crossing gates operated by a watchman, or in some cases from a tower controlling two or more gates.

For the protection of highway-road crossings, bells operated by a track circuit are used in addition to the regular crossing sign.

Fig. 120 shows lever gates operated by hand from a tower. The use of mechanical gates requires a man for each gate and led to the introduction of pneumatic and, later, electrical gates. (See Fig. 120.) The pneumatic gates are made both of the cylinder and the diaphragm types. The electrical gate can be operated with much less effort than the pneumatic gate and a greater number can be controlled by one man. The number controlled from one tower should, however, be limited on account of the danger of striking passing teams when closing the gate.

79. Signs.—Crossing-signs are regulated by the law, which varies radically in different States. The following cases illustrate this:

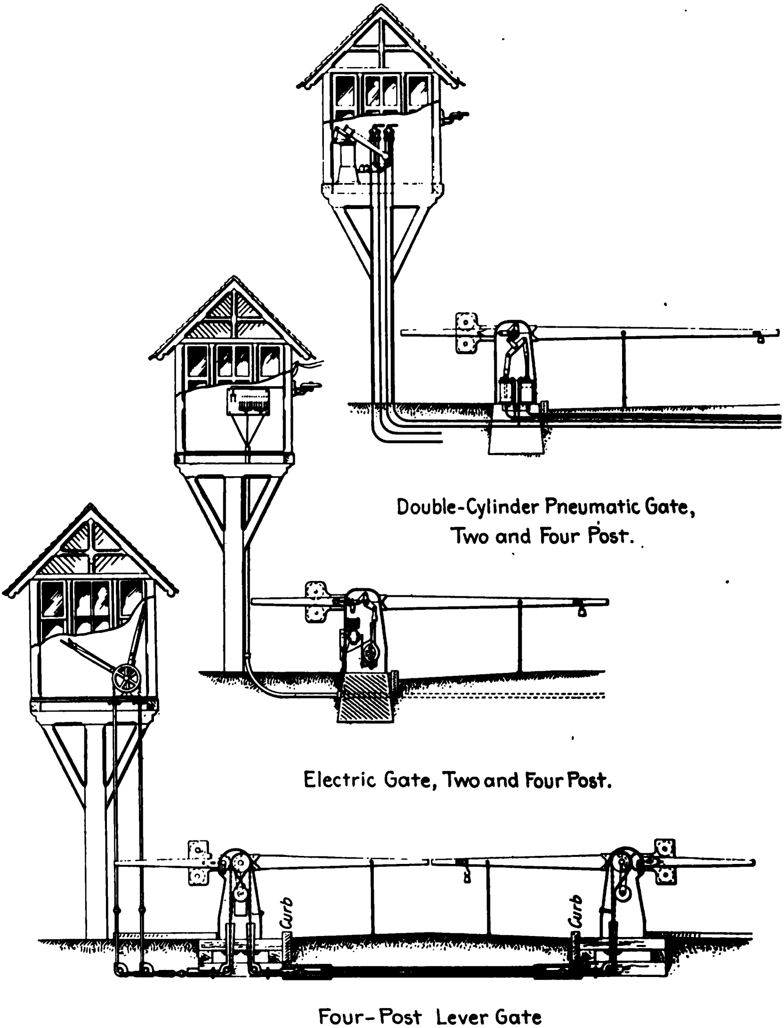


FIG. 120.—Crossing Gates. (Buda.)

Illinois.—Boards, supported by posts or otherwise, elevated so as not to obstruct travel. Letters, not less than 9 ins. Words, Railroad Crossing, or Look Out for the Cars.

Michigan.—Boards, on posts high enough to prevent obstruction of travel. Letters, at least 12 ins. Words, Railroad Crossing.

In Pennsylvania there is no ruling by the Railroad Commission, but, following decisions of the courts that it is con-

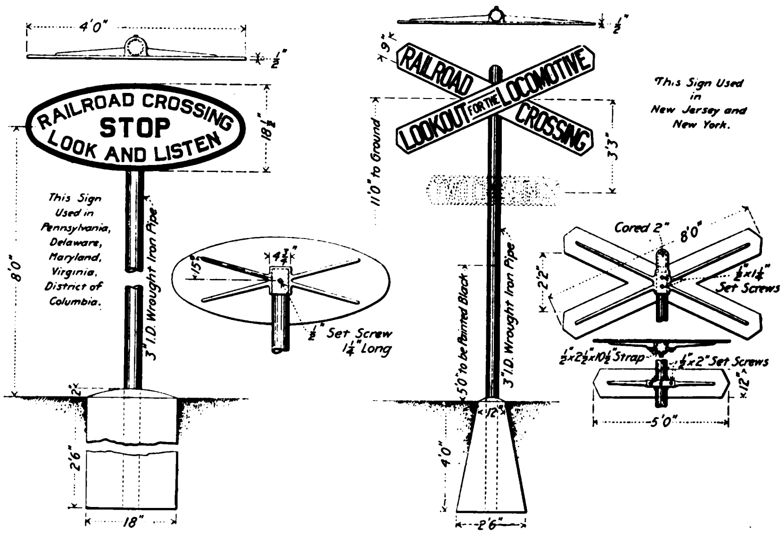


FIG. 121.—Crossing Signs, Pennsylvania Railroad.

tributory negligence on the part of the travelers not to stop, look, and listen, many roads have adopted signs with the words, "Stop, Look and Listen."

The Pennsylvania Railroad has two standard road-crossing signs, one for use in the States of Pennsylvania, Delaware, Maryland and Virginia and the District of Columbia, which has the words, "Railroad Crossing, Stop, Look and Listen." The sign is made of cast iron and the letters and border are raised $\frac{1}{8}$

of an inch. The sign is supported on a 3-in. wrought-iron pipe. Two signs are erected at each crossing, one on each side of the railroad, and when so located that the sign cannot be seen at a distance of 150 ft. from the crossing, an additional sign must be erected at that distance from the crossing.

The other standard sign is for use in the States of New Jersey and New York. This sign has the words, "Railroad Crossing, Look Out for the Locomotive." When two railroads are practically parallel and within 400 ft. of each other, a sign marked "Two Crossings" must be attached.

These signs are illustrated in Fig. 121.

The other signs used on a railway may be divided into the classes given below. These are generally made of wood, iron, or concrete of simple design and containing appropriate words or letters indicating their use.

Danger Signs:
- Overhead caution signs;
- Tunnel caution signs;
- Drawbridge signs.

Operating Signs:
- Slow signs;

Stop signs;
- Water station and trough signs;
- Whistle signs;
- Yard limit signs;
- Snow-plow markers.

Roadway Signs:
- Boundary signs;
- Mile posts;
- Monuments;
- Section signs;
- Subdivision signs.

80. Roadway Small Tools.—Figs. 122 and 123 illustrate tools used in track work. Referring to Fig. 122 the claw bar is used to pull spikes when the rail or ties are changed. The lining bar is used for shifting the track, and the tamping bar to tamp the ballast under the tie; this tool is generally used in stone ballast.

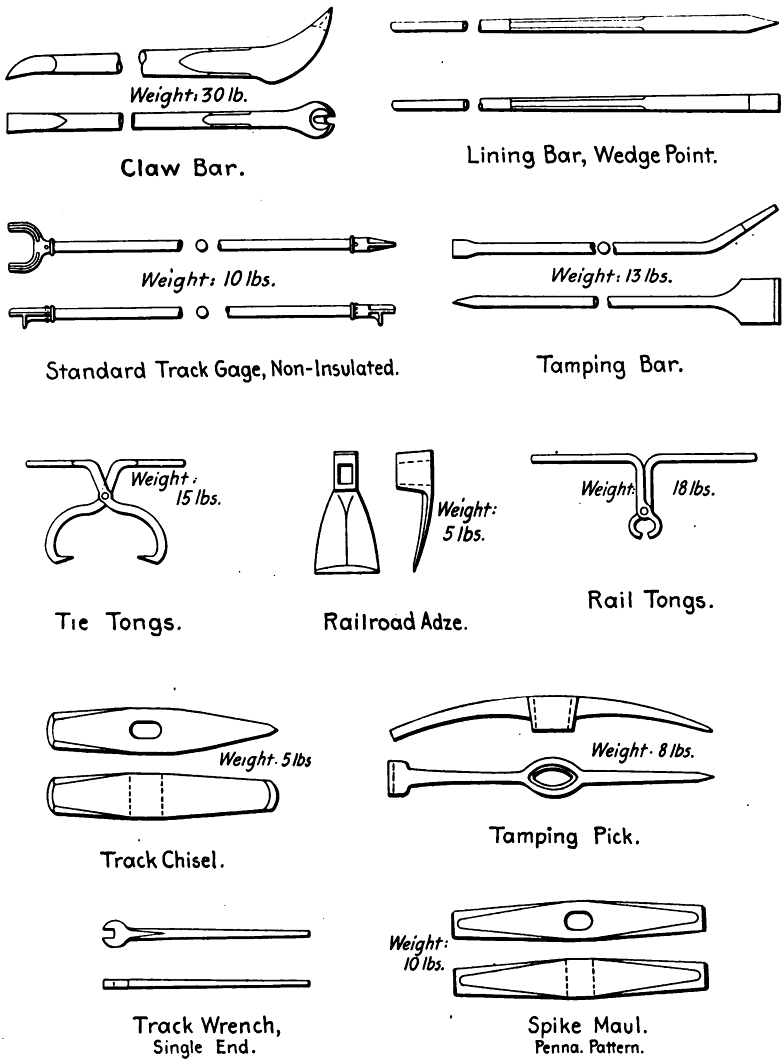


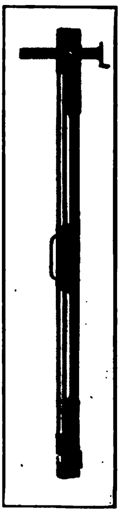
Fig. 122.—Track Tools. (Hubbard.)

The track chisel is used to cut the rail; a line is cut completely around the section and the rail is then raised and allowed to fall on some solid object and is broken by the impact at the place where cut. The track gauge is used to measure the gauge of the track; on curves, where the gauge is widened, shims may be inserted between the rail head and the lug on the gauge to provide for the increase in gauge. The track wrench is usually 33 ins. long, as a greater leverage than this will stretch the ordinary track bolt. The spike maul is used for driving cut spikes and the adze to adze the surface of hewn ties to obtain a level bearing for the rail. The tamping pick is used to tamp the ballast under the tie. The pick seems to be more generally employed for this purpose than the bar shown in the same figure.

In Fig. 123, *A* and *B* illustrate level boards to measure the relative heights of the rails. *C* shows a track drill operated by a ratchet, a drill mounted in a frame in which the bit is driven by means of a chain operating over a hand-turned sprocket wheel; or a gear is frequently employed, as the holes may be drilled faster than with a ratchet. The rails are drilled at the mill, but when necessary to cut them on the ground, as in putting in a switch, the holes for the joint bolts must be drilled by the section men. *E* is a rail bender. It is not necessary to curve the rails on ordinary curves with this machine, but it is employed for bending the stock rail at switches. A track jack is shown in *D*. These are generally of about 10 tons capacity for ordinary section work and are used to lift the track when ballasting. The jack is placed between the ties on the outside of the rail with the step under the rail; the rail is then lifted and held while the ballast is tamped under the adjacent ties.

Table XIII gives lists of tools with which the section should be supplied. In addition to the tools kept at each section, the roadmaster has general tools in stock, such as wheelbarrows, rail benders, cross-cut saws, wire stretchers, post-hole diggers, etc., which may be shipped to sections where special work is being done.

81. Section Work.—The maintenance of the track is under the immediate charge of section foremen. These are experienced



A. Track Level.

B. Step Level Board.

C. Track Drill.

D. Track Jack.

E. Rail Bender.

TABLE XIII

Lists of Tools for Different Size Sections

Kind of Tool.	For Gang Composed of		
	Foreman and Five Men.	Foreman and Three Men.	Foreman and Two Men.
Adzes, with handles	3	2	2
Axes, with handles	1	1	1
Ballast forks	3	2	2
Brace and bits	1	1	1
Brooms	2	2	1
Bars, tamping	6	4	2
Bars, lining	6	4	2
Bars, claw	3	3	2
Cars, hand	1	1	1
Cars, push	1	1	1
Chisels, track	9	9	6
Drills	1	1	1
Drill bits	3	3	3
Files	1	1	1
Flags, red	2	2	2
Flags, green	2	2	2
Flags, white	2	2	2
Flag staffs	6	6	6
Flag hangers	4	4	4
Gauges, track	2	1	1
Gauges, center	1	1	1
Grindstones	1	1	1
Hatchets, with handles	1	1	1
Level boards	1	1	1
Lines for ditching	1	1	1
Lines, tape	1	1	1
Lanterns, red	2	2	2
Lanterns, green	2	2	2
Lanterns, white	2	2	2
Mauls, wooden	1	1	1
Oil cans	2	2	2
Oilers	1	1	1
Picks, clay	6	4	3
Picks, tamping	6	4	3
Punch	1	1	1
Padlock and chain	3	3	3

TABLE XIII—*Continued.*

Kind of Tool.	For Gang Composed of		
	Foreman and Five Men.	Foreman and Three Men.	Foreman and Two Men.
Rail tongs	2	2	2
Saws, hand	1	1	1
Scuffers	6	4	3
Switch locks	2	2	2
Scythes and Snaths	6	4	3
Sledges, with handles	1	1	1
Spike mauls	4	3	2
Shovels, track	6	4	3
Shovels, snow	6	4	3
Spike puller	1	1	1
Tie plate gauge	1	1	1
Torpedoes	50	50	50
Track jacks	2	1	1
Water pail and dipper	1	1	1
Whetstones	2	2	2
Wrenches, track	3	3	3
Wrenches, monkey	1	1	1

NOTE. Each tool house will keep one extra handle for all tools.

trackmen having under them a small force of laborers. The length of a section, or the track under each foreman, is in the neighborhood of 3 or 4 miles of line, but may be considerably larger on lines where the traffic is light. As each part of the road varies in its character, the question of the force to allow each foreman is a matter which requires considerable study on the part of the officer in charge of the maintenance of the road.

All of the items given below must be considered in proportioning the proper force for any section:

Tonnage;	Drainage;
Speed;	Weight of rail;
Curvature;	Kind of ballast;
Subgrade;	Interlocking plants

Evidently the maximum speed over the track would mean very little unless the number of trains moved at this speed were given. The effect of the tonnage passing over the track undoubtedly is a considerable factor in track maintenance; nevertheless, it is so intimately connected with the question of speed, curvature, and character of subgrade, that it is difficult to consider it without reference to the latter.

Table XIV shows the items which enter into the work of maintaining a section and the relative values of each under average conditions.

The purpose of such tables is to enable the officer in charge of track maintenance to proportion his force intelligently, and while it is desirable to enter into considerable detail in regard to the different parts of the track as switches, insulated joints, etc., it would appear that the more intangible elements, such as tonnage, speed or curvature could be covered more satisfactorily by an arbitrary factor selected by the officer in charge.

The value of these characteristic tables lies in the fact that information is given in detail, but sight must not be lost of the fact that there are so many conditions affecting the maintenance of any piece of track that no rule can be successfully put into practice for the proper proportioning of track forces which is not sufficiently elastic to permit of the intelligent consideration of the section as a whole.

In other words, all of the tangible elements of the track can be scheduled as shown by Table XIV, and appropriate values given to each item. The number of units on a section can be added up and the force required to operate the section under normal conditions arrived at with a considerable degree of precision. This equivalent value of the labor required to maintain the section should then be multiplied by some factor which would take into account all of the general conditions of the line.

The question of obtaining efficient foremen is growing to be a very serious matter. These men should be promoted from the track laborers, but with the class of labor now obtainable this is becoming more and more difficult. The problem is being met in many ways, one of which is to increase the force under each

foreman, thus reducing the number of foremen. The use of motor section cars is an aid to this plan and these are now being employed by some roads quite extensively. Fig. 124 illustrates a gasoline section motor car. These cars are sometimes constructed so the engine can be made to drive tools for drilling rails, boring the holes for screw spikes and furnishing power for other miscellaneous uses.

TABLE XIV

VALUE OF DIFFERENT FORCE UNITS EXPRESSED IN EQUIVALENT MILES OF SINGLE MAIN TRACK

	Summer, Apr. 1 to Oct. 31.	Winter, Nov. 1 to Mar. 31.
Tracks, miles:		
Main track	1.00	.70
Second main track	.85	.40
Additional main tracks, each	.70	.35
Passing tracks	.50	.25
Yard tracks	.50	.25
Industrial tracks and others	.30	.15
Turnouts		
Main line and running tracks	.07	.07
Yard and passing tracks	.05	.07
Industrial tracks	.03	.05
Crossings at grade, per track		
Railroad, main line	.03	.03
Railroad, sidings or yards	.02	.02
City streets, main line	.05	.05
City streets, sidings	.03	.03
Village or highway, main line	.02	.02
Village or highway, sidings	.01	.01
Ditches, miles	.50	.10
Insulated joints:		
Main or running tracks	.015	.01
Side or passing tracks	.01	.0075
Switch and signal lamps maintained by section force	.02	.02
Details maintained by section force	.02	.02
Station platform, maintained by track force, 1000 ft	.50	1.00

Other labor-saving apparatus is coming into use, as the pneumatic tie tamper, operated by compressed air, small cranes for handling rails on a section, etc.

In some cases contract work has been resorted to, as in putting new ballast or ties, with excellent results, and it may be that this method or a modification of it by which the men are paid by piece work will be the final solution of the problem.

FIG. 124.—Gasoline Section Motor Car. (Buda.)

In a report on contracting maintenance work by a committee of the Roadmasters and Maintenance of Way Association * the following reasons are advanced why contract work is desirable:

(*a*) A contractor can pay his men what they are worth to him.
(*b*) A contractor always has a following of expert laborers.
(*c*) A contractor can fortify himself against all conditions and can have his own boarding outfit and supply his men with better accommodations than a railroad company.
(*d*) Laborers understand that when they work for a contractor they have to do their part of the work or drop back to less pay or lose their places entirely.

Table XV presents in a general way the kind of section work done in the different months of the year.

* Bulletin, Aug. 10, 1913, p. 113.

TABLE XV

SCHEDULE OF SECTION WORK

Month.	Kind of Section Work.
December January February March first and second weeks	Patrol track, clean snow and ice at switches; tighten track bolts and gauge track; distribute ties and rails; bark ties; repair fences; put in tile drains, etc.
March third and fourth weeks	Spring ditching and cleaning.
April, first and second weeks	Place track in good line and surface.
April third and fourth weeks May June	Put in ties, using Saturdays (and Fridays if necessary) for cleaning and correcting errors in line and surface.
July, first and second weeks	Cut weeds
July, third and fourth weeks August September October	General line and surface.
November	Ditching, sloping, and final cleaning.

82. Fires on Right of Way.—The section foreman should keep the right of way free from all rubbish and combustible material. All grass, weeds and brush should be cut once a year, preferably beginning the work July 1st, and making it the principal occupation until it has been completed, without, however, interfering with proper maintenance of track. The cut grass and brush when dry should be burned, under the supervision of the foreman, who must do such burning with the greatest care to prevent damage to property.

Dry grass, weeds and other combustible matter which is liable to be set on fire by passing engines must be burned thoroughly, whenever it is dry enough to burn, providing such burning can be done without danger of the fire spreading beyond control. No fire should be kindled anywhere along the right

of way by section men or other employees without placing a sufficient force to watch it.

Where the line runs through wooded country the sparks from the locomotive are responsible for a great many of the destructive forest fires which occur every dry season.

Too much importance cannot well be placed upon the question of the prevention of forest fires. The enormous loss from fire in our forests every year is a matter of common knowledge. The value of standing timber destroyed each season from this

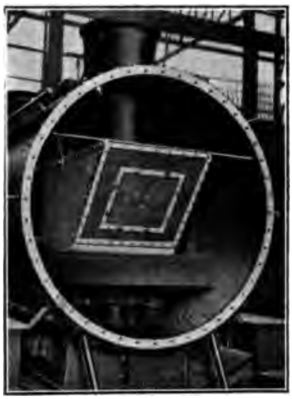


FIG. 125.—Spark Arrester. (Mudge-Slater.)

cause has varied from $25,000,000 to more than $100,000,000, the direct annual loss in recent years averaging considerably over $50,000,000. The destruction of young growth, though never included in estimates of fire damage, is a principal item of loss. The natural restocking of burned-over lands takes place very slowly or not at all.

All experience goes to prove that damage by forest fires is practically preventable. This stage of development has already been reached in Europe. For example, of 7,000,000 acres in Prussia, an average of only 1400 acres, or one-fiftieth of 1 per

cent was burned over each year during the period from 1868 to 1895.

The railroads by working with the State Forestry Officials can accomplish a great deal of good in the way of prevention of fires started by sparks from locomotives.

The Chicago and Northwestern was one of the first roads to use special devices to reduce this danger and have now many of their engines equipped with spark arresters. Fig. 125 illustrates the Mudge-Slater spark arrester.

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CHAPTER X

STATION AND ROADWAY BUILDINGS

83. Local Stations.—At small stations provision is sometimes made for handling freight in the same building that contains the passenger station; this is called a combination station and is

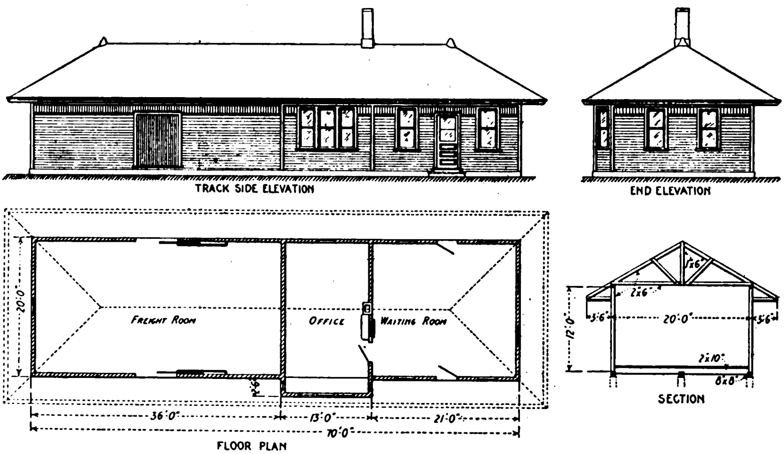


FIG. 126.—Combination Freight and Passenger Station at Bach, Mich., on the Michigan Central R. R.

illustrated in Fig. 126. In moderate-sized stations the general arrangement is to provide a separate building for the freight. This is usually a single-story frame structure with high platforms. When the traffic is light the building is located alongside the main track, but where the traffic is heavy the freight house is placed on a side track. The side track may be located back

of the building, and if this is done it is called an island station. The advantage of the island station lies in the greater unloading platforms at the tracks as compared with greater teaming platforms in the former case.

Stock yards are located at points where cattle are to be shipped. The ordinary stock yard at a local station is made by fencing off one or more pens with a substantial board fence

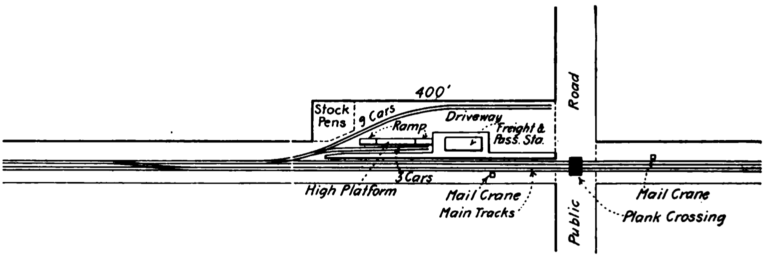
FIG. 127.—Mail Crane. (Barker.)

about 6 ft. high with feed racks and watering facilities. Where the business is considerable, the floor of the pens should be made of concrete. Chutes are provided for loading the cattle into the cars. These are generally made about 4 ft. wide with an easy incline from the level of the pen floor to the car.

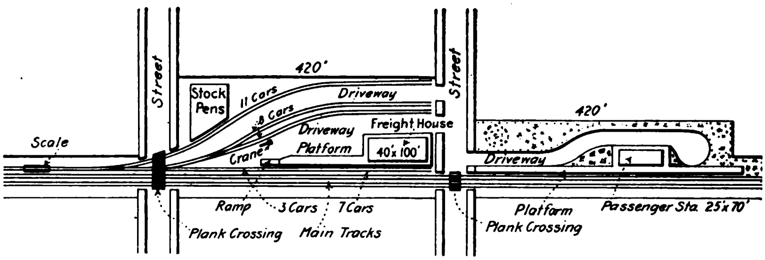
Mail cranes (Fig. 127) are placed at stations where it is necessary for the trains to receive mail without stopping. The crane consists of a post carrying two horizontal bars to which the mail

bag may be attached. These arms are generally arranged so that as soon as the bag is taken by the mechanism on the mail car they automatically assume vertical positions to avoid danger of hitting objects on the train, the clearance of the end of the bars when in the horizontal position being scant.

Fig. 128*A* shows a station layout for small towns with a combination freight and passenger house. The freight-house track



A. Small Towns.



B. Larger Towns.

FIG. 128.—Station Layouts.

has a capacity of three cars and is situated next to a high platform at the freight end of the station. The team track has a capacity of 9 cars and serves the stock pens and the driveway back of the station.

Fig. 128*B* illustrates an arrangement for larger towns with separate buildings for the passenger and freight stations. Here the freight-house track has a capacity of 7 cars and the team

tracks serving two driveways have a total capacity of 30 cars. A small crane is located near one of the team tracks to facilitate the handling of heavy freight to and from the cars. Scales for weighing the cars are placed in the switching lead over which all cars pass to the freight-house and team tracks. The passenger

A. Brick Station at Holly, Colo.

B. Concrete Station at Ponca City, Okla.

FIG. 129.—Local Passenger Stations on the A. T. & Santa Fé Ry.

station is placed apart from the freight house and surrounded by a grass plot with flower beds.

The tendency on most roads is to adopt an artistic design for local passenger stations along the line, and to further beautify these by improving the grounds. Many railroads have a separate department in charge of a chief gardener who has charge

of the station grounds and lays them out and maintains the flower beds and shrubbery.

Fig. 129 shows examples of local passenger stations.

Local stations are generally side stations, although if the topography of the adjacent ground is suitable, they may be made overhead or under stations. The overhead station can be used if the road is in a cut or located on a side hill, and in cities where the track is elevated it is frequently desirable to place the station below the tracks on the street level. On heavy-traffic roads, especially if there are more than two tracks, subways or overhead bridges are constructed to enable the passengers to reach the trains without having to cross the tracks. This is especially true if the line is electrified. In the case of a side station provided with means for the passengers to cross the track, either above or below grade, covered platforms are usually placed alongside the track opposite from the station.

84. Terminal Passenger Stations.—Fig. 130 shows the Pennsylvania Railroad Station at New York, the Union Station at Washington and the Chicago and Northwestern Railroad Station at Chicago. These magnificent structures indicate the trend of recent construction in the erection of passenger terminals in the important cities of this country. The large cost of the modern passenger terminal has given rise to considerable doubt as to the wisdom of spending so much to beautify the building, and it is felt by some railroad men that it is time to call a halt on the present heavy expenditures for passenger stations.

Mr. Howson states in this connection:*

> When it costs the New Haven Railroad $0.31 for each passenger brought into the Grand Central Terminal in spite of its tremendous traffic (I quote from the last annual report of President Elliott), and when another road finds that its share of the cost and fixed charges and the cost of operation of the new Kansas City Station is equal to 37 per cent of its entire gross passenger receipts, it is time for us to consider whether these structures are justified from a sound economic position.

One of the most radical departures from the older type to be found in the modern station lies in the design of the train

* Lecture before the Detroit Engineering Society, January 8, 1915.

Courtsey of Westinghouse, Church, Kerr & Co.)

A. Pennsylvania Railroad Station, New York City; **Seventh Avenue and Thirty-first Street Fronts.**

B. Union Station, Washington.

C. Chicago and North Western Railway, Chicago, Terminal

Fig. 130.—Passenger Terminals.

shed. For many years the train sheds for large railway terminals have consisted of long span roof trusses supporting high roofs, generally spanning all of the tracks.

The height of these stations had its origin in an effort to locate the steel work and skylights as far as possible from the direct effect of the engine gases and smoke, and to improve the ventilation in the shed. The heavy depreciation of these sheds and the poor ventilation obtained has led to the introduc-

Fig. 131.—Bush Train Shed.

tion of the type illustrated in Fig. 131, which is used in nearly all of the recent installations. The photograph is taken in the Hoboken train-shed structure of the Lackawanna and shows an engine standing within the shed underneath the smoke duct.

85. Terminal Freight Stations.—The question of freight terminal stations is a very large one, and in order to form some conception of the problem the following description of the Soo Line freight terminal in Chicago is given.*

* The author is indebted to the Leonard Construction Co. for the details of this terminal.

Referring to Fig. 132, the terminal is located near the center of the business and manufacturing district of the city and covers eleven city blocks.

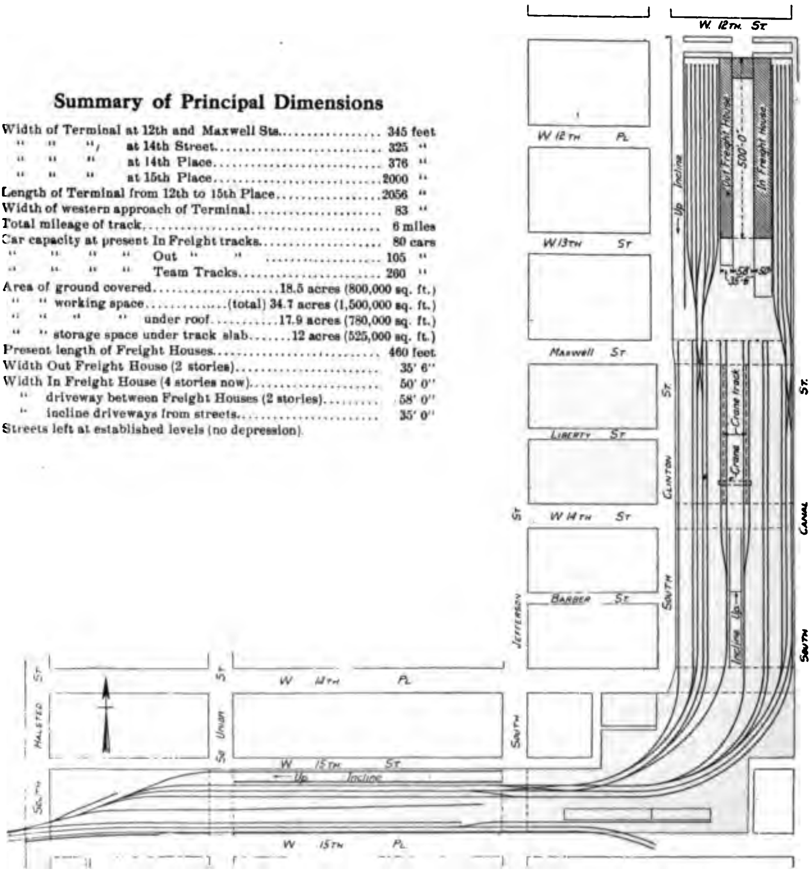
The City of Chicago would not permit the building of a terminal of this size at street level, or with any grade crossings. The problem resolved itself, therefore, into two alternate possibilities; retaining walls could be built along the streets and the area filled, with bridges across the streets, and large terminal storage houses provided in addition to the freight houses required for the actual handling of the freight to and from the cars.

The second possibility is the one embodied in the plan decided upon. The terminal tracks in this arrangement are all carried on a deck structure continuing uninterruptedly across the streets, almost the entire area of the property beneath this structure, excepting the five streets left open for traffic, being available for storage purposes, amounting in all to over 600,000 sq. ft.

All of this space is at the street level directly accessible to teams for city distribution and served also by the tracks of the Chicago Terminal Company. From the street the track deck is reached by two inclined driveways, one from Twelfth Street on the north, and the other from Fourteenth Place on the south.

The freight houses and office building are located at the north end of the terminal. The main in- and out-freight houses are built 460 ft. long. The in-freight is four stories high, it is 50 ft. wide with a floor space of about 100,000 sq. ft. This house is served by five tracks along Canal Street with a capacity of 80 cars. Five elevators distribute the freight received on the second floor to the upper and lower floors. One tunnel elevator serves the second floor directly. Three spiral chute conveyors are also installed.

The out-freight house is two stories high and is served by eight tracks with a capacity of 105 cars. The building is 35 ft. 6 ins. wide with a floor space of 65,000 sq. ft. The freight is received from the driveways through 16 team doors on the first floor, and 18 on the second. Two freight elevators serve the first and second floors. A 10-ton 20 ft. radius pillar crane for



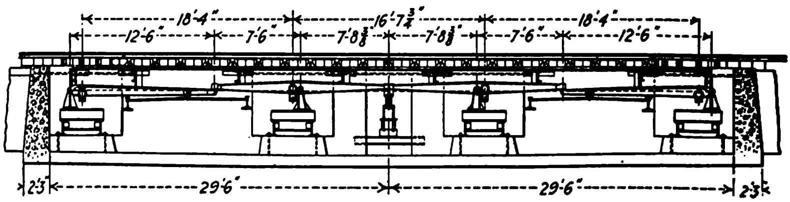
Summary of Principal Dimensions

Width of Terminal at 12th and Maxwell Sts.	345 feet
" " " at 14th Street	325 "
" " " at 14th Place	376 "
" " " at 15th Place	2000 "
Length of Terminal from 12th to 15th Place	2056 "
Width of western approach of Terminal	83 "
Total mileage of track	6 miles
Car capacity at present In Freight tracks	80 cars
" " " " Out " "	105 "
" " " " Team Tracks	260 "
Area of ground covered	18.5 acres (800,000 sq. ft.)
" " working space (total)	34.7 acres (1,500,000 sq. ft.)
" " " " under roof	17.9 acres (780,000 sq. ft.)
" " storage space under track slab	12 acres (525,000 sq. ft.)
Present length of Freight Houses	460 feet
Width Out Freight House (2 stories)	35' 6"
Width In Freight House (4 stories now)	50' 0"
" driveway between Freight Houses (2 stories)	58' 0"
" incline driveways from streets	35' 0"
Streets left at established levels (no depression).	

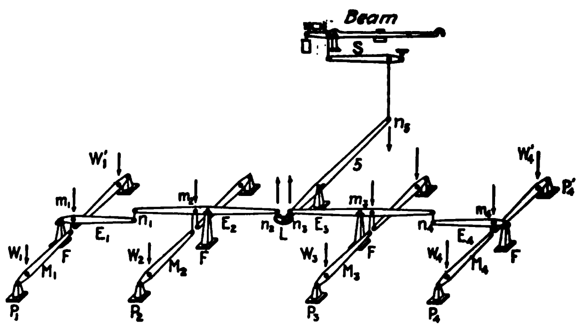
FIG. 132.—Soo Line Freight Terminal, Chicago.

handling heavy castings, etc., is located on the out-freight platform, so as to serve cars, trucks and platform from one fixed position.

The team tracks are located south of Maxwell Street and have a total capacity of 259 cars, which can be greatly increased when the need arises. A traveling crane serves four tracks near the south incline driveway. A 9 ft. by 20 ft. auto-truck scale



A. Bessemer and Lake Erie R. R. (Am. Ry. Bridge & Bldg. Assn.)



B. Diagram of. (Epright.)
FIG. 133.—Track Scales.

is located in a central position with regard to the inclines and driveways. The flat unobstructed deck permits the tracks to be rearranged at any time as experience may show to be desirable for the more efficient operation of the terminal.

86. Track Scales.—Fig. 133*A* shows the scale used on the Bessemer and Lake Erie Railroad built by the Carnegie Steel

Co. In this scale the overhang to the track rails brings the impact of the car entering the scale on the weigh bridge at a point one-fifth the distance between the end knife edges and those of the first section next to them.

In the earlier scales no overhang was provided for, and the wheel of the oncoming car when going across the gap between the scale rail and the track rail would strike a blow on the weigh bridge beyond any support, thus putting the full weight of the wheels on the first section with a leverage increasing the load considerably, and also having a tendency to lift the bridge from the bearings of the second section.

Most roads now use a design with an overhang. The Pittsburgh and Lake Erie Railroad use an easer rail in addition to the overhang. The function of the easer rail is to carry the wheel over the gap, which is accomplished by means of an angle bar with an upward projection which supports the tread of the wheel.

When the scale is on a hump or other track upon which cars are switched which may not require weighing, dead rails, or rails independent of the weighing bridge of the scale are frequently employed to save useless wear of the scales.

The diagram in Fig. 133*B* shows how the weight of the car is carried to the beam. The following description given by Mr. Epright explains the operation of the scale:*

The weight of the platform and load is carried on the main levers M, M_1, M_2, M_3, etc., at the points marked W. One end of each of the main levers is supported on a supporting post mounted on the foundations at the points marked P_1, P_2, etc., and the other end transmits the force of the load to the extension levers E_1, E_2, E_3, E_4, at the points m_1, m_2, m_3, and m_4. The extension levers run parallel to the track and are supported on piers at the points marked F. The ends of these levers are connected by links marked n_1, n_2, n_3, and n_4 by means of which the pressure of the load is transferred from the points m_1, m_2, etc., to the fifth lever "5" at L. The fifth lever conveys the combined force from all of the levers to the shelf lever S, from which it is conveyed to the beam.

* Standard Track Scales on the Pennsylvania R. R., A. W. Epright, Sixth Annual Convention on Weights and Measures, Bureau of Standards, Washington.

87. Roadway Buildings.—At crossings where a flagman is employed watchmen's shanties are provided. These houses, as the name implies, are used to afford shelter to the watchmen employed by the railroad at crossings or bridges and in yards for the switch tenders. They are generally built of wood and are provided with a stove, bench and locker-room.

The tool or section house is used for storing the hand car and tools used by the section gang. There is usually one house

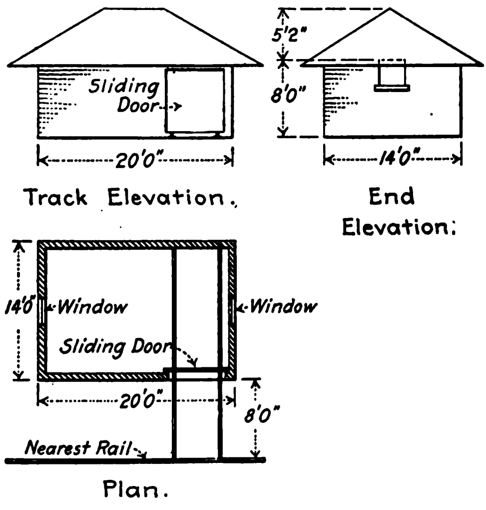


FIG. 134*A*.—Section Tool House, Roadway Buildings. (Am. Ry. Eng. Assn.)

for each section of the road. The building should be located alongside the track, preferably on a siding, so that the hand car may be lifted on and off the track at the minimum risk. There should be sufficient space between the track and the house to enable the car to be run out of the house and clear trains using the track.

Fig. 134*A* shows the house recommended by the American Railway Engineering Association for Class A roads, or roads having more than one main track.

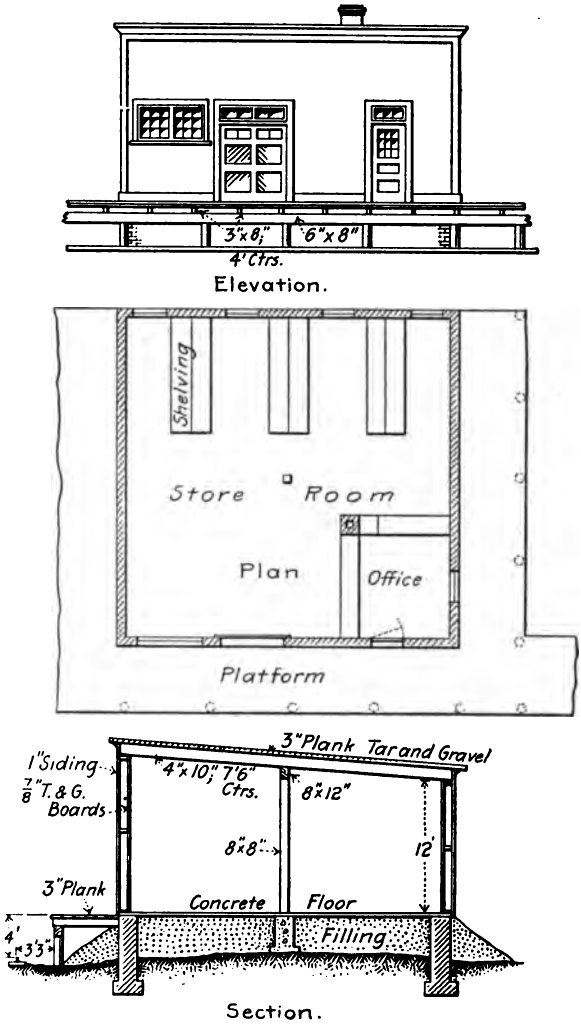


FIG. 134*B*.—Store House, Roadway Buildings. (After Orrock.)

The house is 14 ft. by 20 ft. with the long dimension paralle to the track and has a sliding door 8 ft. in the clear located at the extreme end on the track side to permit the storing of the hand car.

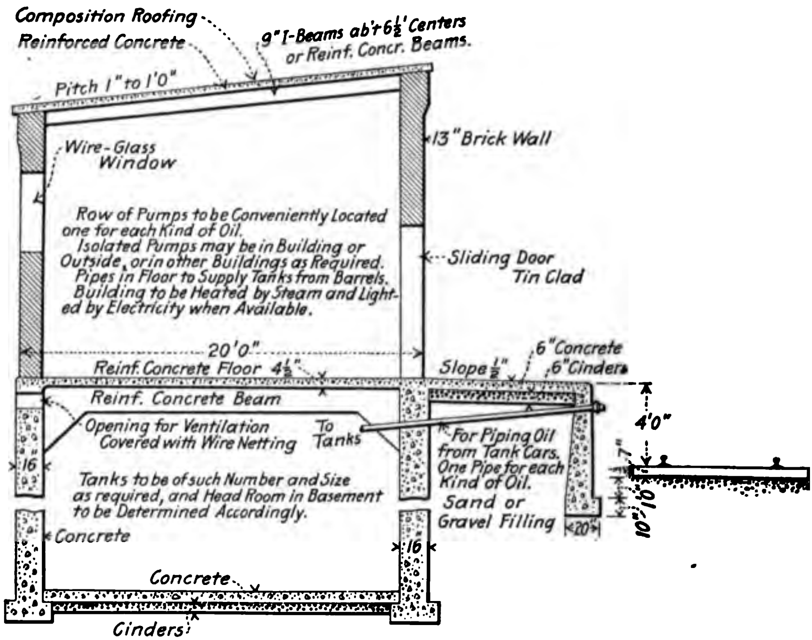


FIG. 134C.—Oil House, Roadway Buildings. (Am. Ry. Eng. Assn.)

For smaller roads or branch lines the house may be reduced in size to 10 ft. by 14 ft. with the short dimension parallel to the track and provided with a double swinging door, swinging out, on the end nearest to the track for the entrance of the hand car. The building in that case may rest on wooden posts, unless the location can be permanent, in which case brick or concrete posts may be substituted.

When accommodations are hard to find for the laborers on the line of the road, section dwelling houses are frequently erected by the company for the use of their employees.

The storehouse is used for supplies for general service in maintenance and operation. It is usually a frame structure and should be provided with the necessary bins and racks to hold the stores. The oils for rolling stock and for use in the shops are sometimes kept in the storehouse, but more frequently a separate building is provided on account of the danger from fire.

Fig. 134*B* illustrates a small storehouse 30 ft. by 30 ft. with platform.*

Fig. 134*C* shows a cross-section of a typical oil house, 20 ft. by 40 ft. The American Railway Engineering Association recommends the following in regard to oil houses:†

1. Where practicable, oil houses at terminals should be isolated from the other buildings.
2. Oil houses should be fireproof, and the storage in large houses should preferably be underground or in the basement.
3. Oils that are stored in sufficient quantities should be delivered to the tanks in the house direct from tank cars. For oils that are stored only in small quantities provision should be made for delivery to storage tanks from barrels by pipes through the floor.
4. The delivery system from the storage tanks to the faucets should be such that the oil can be delivered quickly and measured automatically. The delivery should also be such that there will be a minimum of dripping at the faucet and that the dripping be drained to the storage tanks.
5. Opening for ventilation should be provided above the level of the top of the tanks.
6. Lighting, when required, should be by electricity and heating by steam.

* Railroad Structures and Estimates, J. W. Orrock, 1909. John Wiley & Sons, New York, p. 130.

† Manual, 1911, p. 123.

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CHAPTER XI

WATER STATIONS

THE essential features of a water station are:

1. The source of water supply.
2. The pumps for elevating the water into the tank.
3. The power used to drive the pumps.
4. The pipe lines for conducting water to the tanks and stand pipe.
5. The tanks for storing the supply of water.
6. The stand pipes or track tanks for delivering the water to the locomotives.
7. The apparatus for treating the water when it is not adapted for use in the boilers of the locomotives without some preliminary treatment.

In selecting the location for the station an investigation of the permanency and volume of water available at all times of the year must be made, and if there is any doubt as to the water's suitability for engine use it should be analyzed to determine this.

88. Pumping.—The pumps generally used are geared in the case of gas or oil engines (Fig. 135) and connected directly to the piston when steam is employed.

When the water is pumped from deep wells a deep-well pump is used. The piston of the pump operates at the end of a long rod and raises the water. Fig. 136 illustrates a Fairbanks-Morse horizontal-geared base engine connected to one of their deep-well packing heads, of the displacement plunger type. This arrangement dispenses with a walking beam for operating the deep-well pump. Hydraulic rams are sometimes employed where

FIG. 135.—Combined Gasoline Pumper. (Fairbanks-Morse.)

FIG. 136.—Geared Base Engine Operating Deep Well Pump. (Fairbanks-Morse.)

a large supply is available and the conditions are otherwise favorable for elevating the water by this means. A few installations of compressed-air pumping have also been made.

Steam and gasoline engines are probably used in this service to a greater extent than any other form of power. In regions where slack coal is available to be burnt under the boilers the steam engine predominates, but the gasoline engine, where inexpensive slack coal is not to be had, has a large use, probably on account of the small amount of attention it requires. Electric pumps are nearly automatic in their action and where electrical energy is cheap these are to be recommended.

Owing to the increased cost of gasoline, other forms of power are being investigated to take its place (see Table XVI). Crude oil, which is a product obtained in the manufacture of

TABLE XVI

COMPARISON OF COST OF PUMPING WATER

(Am. Ry. Bridge and Building Assn. Proceedings, 1911, p. 114)

Boiler.		Pump.	Total Head (Feet)	Fuel.		Cost per Horse Power Hour.
Type.	Horse Power			Kind.	Price.	
Vertical......	45	Duplex.......	104	Mine run coal...	$2.00	$0.0316
Locomotive...	60	Duplex.......	196	Mine run coal...	2.00	0.0306
Vertical......	45	Duplex.......	139	Mine run coal..	2.00	0.0354
Locomotive ..	60	Comp. duplex.	220	Screenings.....	1.00	0.0097
Walled in.....	150	Comp. duplex.	220	Screenings.....	1.00	0.0070
Walled in.....	80	Duplex.......	37	Screenings.....	1.00	0.0210
Motor.......	25	D. A. duplex..	49	Elec. current...	.04	0.0420
Walled in.....	40	Deep well.....	93	Screenings.....	1.00	0.0230
Vertical......	40	Deep well.....	51	Mine run coal..	2.00	0.0640
Gasoline......	12	Deep well.....	108	Gasoline.......	.12	0.0600
Vertical......	45	Air compressor.	230	Mine run coal..	2.00	0.0320
Gasoline......	6	Single........	61	Gasoline.......	.12	0.0402
Gas engine, oil Fixture.....	6	Single........	59	Power distillate.	.03¼	0.0094
Oil engine....	12	S. A. Triplex..	143	Fuel oil........	.02	0.0026
Gasoline......	6	Double acting.	71	Gasoline.......	.12	0.0486

gasoline, has for some time been considered as a possible substitute for the refined oil used in the internal combustion engine. The crude oil is very much cheaper than gasoline, but the earlier experiments were not very successful on account of the heavy carbon deposit left on the cylinders, which seriously interfered with the operation of the engine. Of later years better results have been obtained, and it would seem that this fuel may eventually prove a satisfactory substitute for gasoline.

Oil engines have been built using the heat of combustion in several ways to develop power. The ordinary explosion type of engine, in which the combustion is completed in so short a time that practically no change in the cylinder volume takes place during combustion, employs a method of using heat much more efficient than the method available for a steam engine, yet far less efficient than is actually possible. In an attempt to realize in an engine the most favorable method of using heat, Dr. Rudolph Diesel, of Munich, proposed in 1893 what has proved to be, from a thermal standpoint, the most economical heat engine so far devised, and the one that most nearly approaches theoretical maximum efficiency.

In the Diesel engine the mixture is not exploded by a spark as in the ordinary gas or gasoline engine, but by the high temperature obtained by compressing the mixture in the cylinder; a more uniform and certain explosion is thus obtained, enabling a greater range of fuel to be used with good results. The efficiency is relatively very high, but on account of the unusual pressures employed to get the necessary heat to explode the mixture an expensive construction is required.

Producer gas in the small units required in this service has to be made from anthracite coal, which costs about twice what it is necessary to pay for bituminous coal. Even under these conditions the cost of power from the producer is much less than in the case of the gasoline engine, and on account of the steady load on the engine and consequent even draft on the producer it is working under favorable conditions to produce its greatest efficiency.

The author installed a small producer gas plant in water

station service in 1909. The plant consists of a 21 H.P. Fairbanks' Morse Suction Gas Producer, which furnishes gas to a remodeled 20 H.P. gasoline engine made by the same company, the engine being the same that was formerly used at the station with gasoline fuel. A brake test on the plant shortly after it was installed showed that it was developing 1 B.H.P. hour per 1.5 lbs. of coal.

The station has shown a marked saving since the producer was installed over the cost of operating the old plant, and in general it appears that where the pump is required to be run for 8 or 10 hours out of the 24 so that the stand-by loss is not too great in the producer a producer gas plant will effect a saving over gasoline engines.

The pipe lines are generally of 10 to 14 in. cast-iron pipe. In most cases this is laid with leaded joints, but the use of a pipe with a ball and socket joint with the ends of the sections bolted together has been quite successful in a number of installations.

Wood pipe lines have been used in the West where it is necessary to convey the water long distances. The wood pipe used in laying the line from Bonito to Pastura (250 miles long, varying from 16 ins. to 3½ ins.) for the El Paso and Southwestern Railway was machine-made, spirally wound, wood-stave pipe, made in sections from 8 to 12 ft. long with the exterior surface covered with a heavy coat of asphalt. The pipe was wound with flat steel banks, of from 14 to 18 gauge and from 1 to 2 ins. wide.*

The line should be laid with long radius elbows and gate valves used throughout, especially between the tank and the stand pipes, to reduce the friction to a minimum and obtain as great a head as possible for rapid delivery of water to the engine tank.

89. Tanks.—Storage tanks were formerly made to hold 50,000 to 80,000 gallons, but now quite generally have a capacity of

* The Water Supply of the El Paso and Southwestern Railway from Carrizozo to Santa Rosa, N. Mex., J. L. Campbell, Trans. Am. Soc. of Civ Engrs., December, 1910, Vol. LXX, pp. 164–189.

100,000 gallons, although the Pennsylvania seems to prefer a 50,000-gallon unit for their wood tanks on account of greater safety in case one tank is destroyed. The older tanks were usually made of wood and supported on a wood or steel substructure. Fig. 137*A* shows a wood tank on a steel substructure. In recent years concrete tanks and steel tanks have come into quite common use.

The steel tank shown in Fig. 137*B* is typical of the design prepared by the Pennsylvania Railroad engineers. The height of the top of the tank is 48 ft. and of the bottom 22 ft. These are made of 50,000

A. Wood Tank, Steel Substructure. *B*. Steel Tank.

FIG. 137.—Water Tanks.

75,000 and 100,000 gallons capacity. The leg from the bottom of the tank to the ground is about 4 ft. in diameter and is not insulated. In colder climates, as in the case of the steel tanks on the Grand Trunk Pacific, a heating plant is provided and the water in the leg is heated to prevent the formation of ice.

Fig. 138 shows a type of railroad tank used in cold climates where it is necessary to heat the water during the winter season.

It will be noted that at the base of the riser pipe provision has been made for installing a stove and the entire riser pipe is enclosed in a two-ply frost case having suitable doors, which permit of access to the interior of the steel riser. The arrangement of spouts and fittings, which have been found very satisfactory, is shown in some detail on this drawing. Above the spout valves on the interior of the tank is shown an ice rack. This is to protect valves in the event of ice forming inside of the tank in spite of the heating system. The spout inlet valves are located as near the center of the riser pipe as possible so they will be protected from the cold.

90. Stand Pipes.—Stand pipes are used to deliver the water to the engine when the latter is at rest, and track tanks when it is desired to take water when the train is in motion.

The stand pipe, or water column, as it is sometimes called, consists of a vertical pipe with a horizontal pipe projecting at right angles near the top of the column. The column is supported on bearings which permit it to be rotated through 90 degrees from its normal position (i.e., with the horizontal pipe parallel to the track) so as to bring the end of the horizontal pipe over the engine tank. The column should be arranged to lock parallel to the track. In Fig. 139*C* this is accomplished by means of the cam and rollers shown in section *MM*. The stand-pipe valve is located at the base of the vertical pipe and admits the water to the column. The valve is generally automatic or semi-automatic in its action, and is controlled by the fireman on the engine tank by means of a lever on the horizontal pipe or spout connected through suitable levers to the operating mechanism of the valve. This is shown in Fig. 139*C*; the sliding collar *G* is

connected to the levers on the spout and its motion is transmitted to the small operating valve *F*.

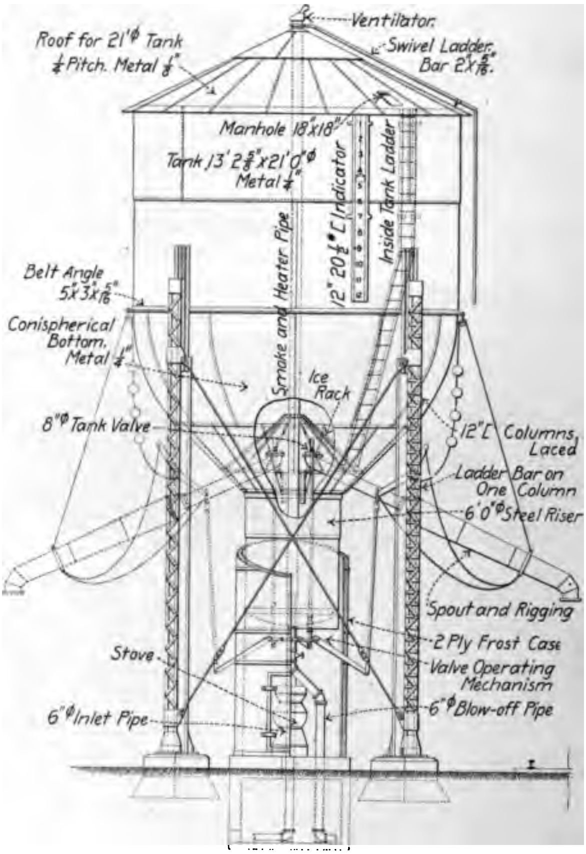
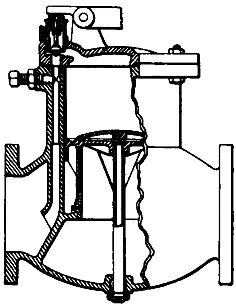
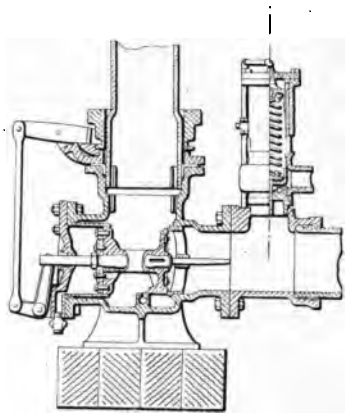


FIG. 138.—Steel Tank with Heater. (Pittsburgh-Des Moines Steel Co.)

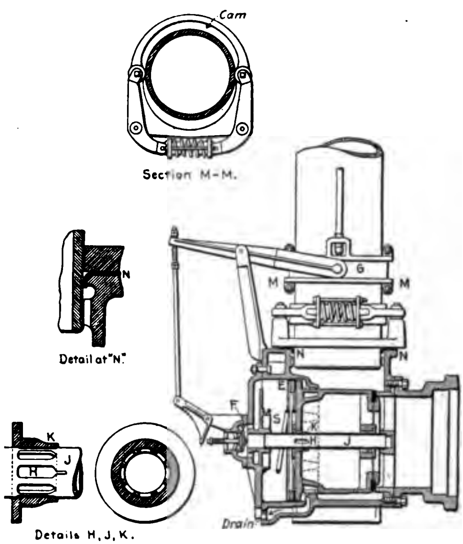
The investigation of the friction in stand pipes and standpipe valves made several years ago by the Committee on Water Service of the American Railway Engineering Association has



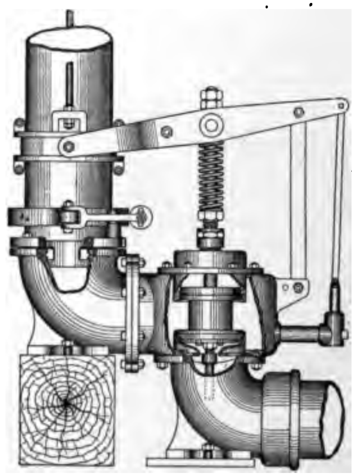
A. Gulland Valve.



B. Sheffield Valve.



C. U. S. Valve.



D. Mansfield Valve.

Fig. 139.—Stand Pipe Valves.

thrown much light upon the proper design of this apparatus. It was found that the loss of head, especially in the stand-pipe valve, was excessive, and to obtain the necessary flow of water a much larger pipe was required than would be the case with proper design.

Table XVII shows the loss in head found in the different valves and columns tested at the University of Illinois Engineering Experimental Station under the direction of the Committee.

TABLE XVII

LOSS OF HEAD IN 10-IN. WATER COLUMNS. (TALBOT AND ENGER)

(The loss is given in feet of water for the discharge indicated.)

Designation.	3000 Gals. per Min.		5000 Gals per Min.	
	Valve.	Total.	Valve.	Total.
I	12.6	15.5	35.0	43.0
II	12.6	17.7	35.0	49.0
III	11.3	14.2	31.3	39.3
IV	11.1	16.2	31.0	45.0
V	6.4	12.5	18.0	35.0
VI	16.3	23.5	45.0	65.0
VII	20.0	26.1	55.0	72.0
VIII	9.0	13.0	25.0	35.5
IX	6.4	13.1	17.8	36.5
X	13.5	20.3	37.5	56.5
XI	1.6	8.7	4.3	24.0
XII	6.1	8.9	17.0	24.6
XIII	6.2	12.1	17.3	33.0
XIV	6.5	8.9	17.8	24.6

Valve XI was a hydraulically operated gate submitted by the author to determine what would be the least possible loss which it would be practicable to have in a stand-pipe valve.

These tests showed that the loss of head was excessive in most of the valves used in the service, and as a result many of the designs have been modified to conform to more correct hydraulic principles.

The question of water hammer in these valves is a serious one and is overcome, or partially overcome, in the valves in several ways. Referring to Fig. 139*A*, the Gulland valve has V-shaped openings through which the water passes and as the valve closes the water is gradually shut off, stopping the flow without shock.

In the valve shown in Fig. 139*C*, *E* is the operating piston and valve packed with a cup leather. At *F* is the auxiliary valve, operative from the delivery spout by means of a system of levers. At *S* is the assisting spring, which assists the valve to begin the motion of closing.

At *H* are slots in the brass pipe *J*, through which water from the main enters to close the valve. These slots are surrounded by a bushing *K*, which acts like a valve to gradually close them, until, when the valve is near the end of its movement, the slots are so nearly closed that the valve comes gently to its seat.

In the Mansfield valve, Fig. 139*D*, the valve is controlled directly by levers and is not hydraulically operated, as is the case with the valves shown in Figs. *A* and *C*. This valve is nearly balanced to make the valve easy to operate. It will be observed that in the case of water hammer when the valve is being closed the excess pressure will cause the spring to be compressed and the valve will open, the spring acting as a relief or shock absorber.

The relief valve shown in Fig. 139*B* acts in the same way and opens when the pressure caused by the water hammer rises beyond a certain point.

It is interesting to note in this connection that the injurious effects of water hammer occur only during the last part of the closure, and the pressure does not rise until the valve is very nearly closed.

This is an important point and one that it is well to emphasize in the design of stand-pipe valves. The long column of rapidly moving water in the pipe line if brought to rest without proper provision to absorb the shock will damage the valve and have a tendency to open up the joints of the pipe line. On the other hand if the valve be closed more slowly than is necessary throughout the entire stroke, then the time required for the engine to

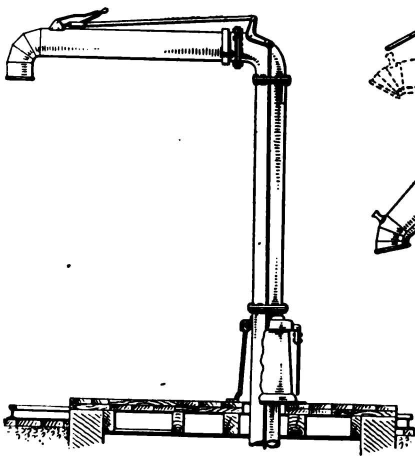
take water will be unusually long. The ideal arrangement appears to be a rapid movement of the valve for about 85 per cent of the closure and then a gradual reduction of the opening until final closure is effected.

Fig. 140 illustrated methods of delivering water to the engine tank. Fig. 140*A* shows a rigid spout column; to prevent loss of water a metal sleeve is sometimes swung from the end of the spout, or the anti-splash or honey-comb device shown in *C* is used to direct the water. The adjustable spout shown in *B* is now generally employed to prevent loss of water between the spout and tender. *D* and *E* present other arrangements of spouts. The spout was formerly nearly always attached to the tank, as shown in *D*, but this method is now used only on unimportant lines, as it affords less flexibility of arrangement than the individual stand pipes which may be placed at the most convenient location for the engine to take water irrespective of where the tank is placed.

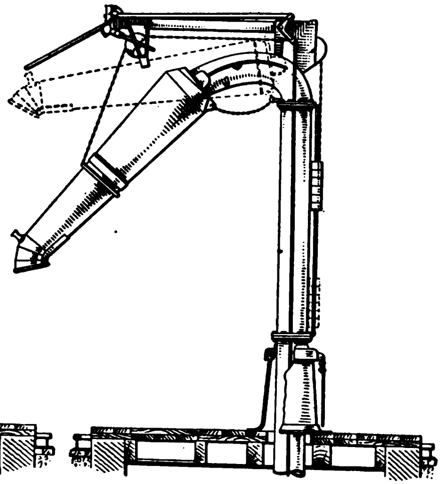
91. Track Tanks.—The track tank Fig. 141 consists of a steel tank about 1400 to 1800 ft. long * located between the rails and into which a scoop is lowered from the bottom of the engine tender. On account of the inertia of the water and the speed of the train the water is forced up into the engine tank.

The principal points of divergence in track tank construction lie in the methods employed to heat the water and prevent its freezing in the tank in cold weather. The systems employed for this purpose are *first,* the direct heating by means of jets of steam entering the water at frequent intervals from the side of the tank, and *second,* what is known as the circulation system in which the cold water flows from the tank and is forced up through other openings by an injector which at the same time raises the temperature of the water. The latter system is much the more expensive of the two and while it is used by the Pennsylvania, Lake Shore and other important roads, it would hardly seem that the benefits derived warrant the extra cost of its construction.

* Tanks 2000 ft. or even 2500 ft. in length are used on some roads where trains are double headed, to provide the necessary capacity for the two engines to obtain water.



A. Rigid Spout.



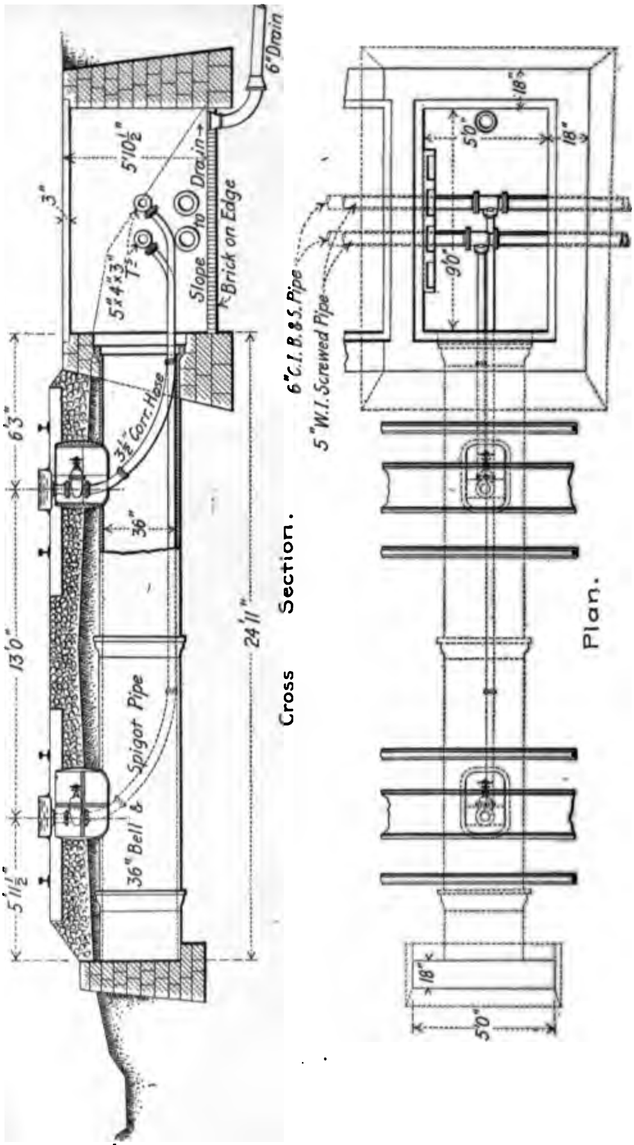
B. Adjustable Spout.

C. Anti-splash Nozzle.

E. U. S. Wind Engine and Pump Co.'s Spout on Coaling Bridge.

D. 60,000-gallon Tank with Spout on Tank.

FIG. 140. Methods of Delivering Water to Engine Tanks; Spouts.



A. Circulation System, Tunnel under Tracks.

FIG. 141.—Methods of Delivering Water to Engine Tanks; Track Tanks.

Fig. 141*C* shows a track tank on a four-track line. In the center between the middle tracks may be observed the box containing the steam line for heating the water in the troughs by the jet system, which was formerly used. This has been superseded and the circulation system is now employed at the station. The end of the tunnels containing the pipes for the sytem can be seen outside of the right-hand track. The picture is interesting as showing also the inclined approaches to the tanks, the dapping of the ties where the center tanks have been shortened and the stone flagging used to prevent the water which is thrown out of the tank washing away the ballast.

92. Water-treating Plants.—Hard water can be softened before it is put into locomotive boilers by treating it with chemicals. Water whose hardness is due to carbonates of lime and magnesia can be softened at a moderate expense for chemicals by the use of lime alone, without adding any soluble salts to the softened water. Water whose hardness is due to sulphates of lime and magnesia can be softened, but at a greater expense, by the use of soda ash, a more expensive chemical. In this case soluble sulphate of soda will be added to the softened water, increasing the tendency to foam.

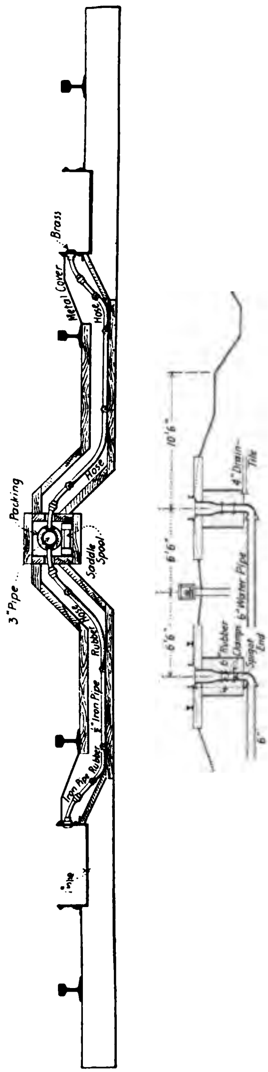


FIG. 141*B*.—Jet System.

The mechanical methods of modern water softeners differ widely, but consist of two general types, the continuous and the intermittent. In the continuous type the natural water enters the softener, passes through one or more chambers and finally flows off into the storage tank, the sludge resulting from the chemical reactions being precipitated to the bottom of the softener and drawn off at intervals as required. In the intermittent type the water passes into settling tanks and is, after the solids have been precipitated, drawn off into storage tanks ready for use.*

FIG. 141C. Track Tank on L. S. & M. S. Ry.

A great deal of the engine water does not require treatment, but in cases of bad or contaminated water such, for example, as that obtained from a source of supply which receives the pumpings from coal mines, treatment has effected a considerable saving in engine repairs, besides giving much better steaming qualities in the boilers.

* See Manual Am. Ry. Eng. Assn., 1911, pp. 341–349.

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CHAPTER XII

FUEL STATIONS

THIS is a subject of considerable operating as well as engineering importance, but one which it is hard to reduce to definite rules on account of the varying conditions at different localities. Within certain limits, however, general rules can be given for the selection of proper types.

When the quantity of coal used is small and in particular at less important terminals where an engine lays over night and the night watchman does the coaling, a good arrangement is to coal directly from the cars to the tender. The coal cars are placed on a side track, slightly elevated, and so located that the watchman can easily shovel the coal into the tender.

93. Platforms.—If a greater number of engines are to be handled, or if the engines have to take most of the coal during the daytime, when they are in continuous service, a platform is built with either a hand or air derrick operating a small bucket of about one ton capacity, as shown in Fig. 142. This arrangement may be used to advantage for handling about 1000 to 1500 tons a month.

94. Docks.—Before the invention and general use of elevating machinery for large coaling stations, coal chutes were employed in which the coal was unloaded by hand from the cars into storage pockets; from the pockets it was run into the tenders of the locomotives as occasion required. These chutes (Fig. 143*A*) consisted of an elevated track about 19 or 20 ft. above the level of the engine tracks with an inclined trestle approach of 5 per cent, up which the coal cars were pushed by a switch engine. On each side of this elevated track were located a row of pockets,

having inclined bottoms. The coal was stored in these pockets, each of which had a gate for delivering the coal to the engine tenders. The principal objection to this type is the high cost of handling the coal, which must be shoveled out of the cars by hand at an expense of from 10 to 15 cents per ton.

With the introduction of bottom-dumping cars, similar in design to the ballast car shown in Fig. 105*B*, a new type of coaling station was developed with a view of eliminating the manual handling of the coal from the car to the pockets.

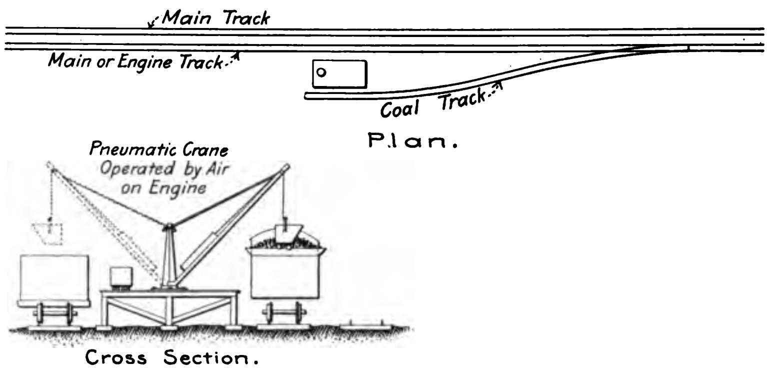


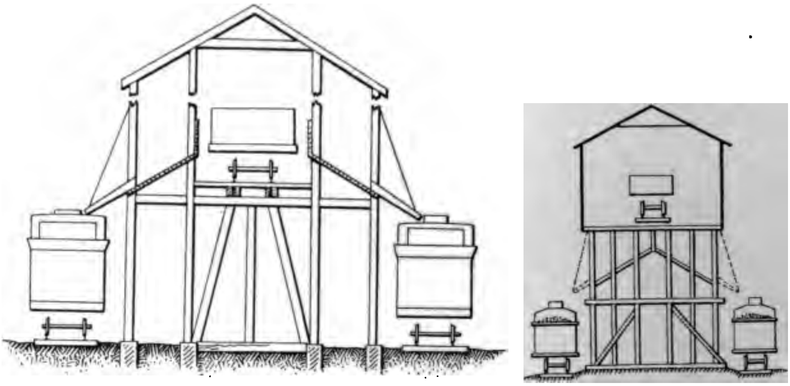
Fig. 142.—Coaling Platform.

This chute (Fig. 143*B*), as in the type which preceded it, had an elevated track reached by an inclined trestle approach, but the bins or coal pockets were located below the track and the coal was dumped into these, filling them by gravity. The elevated track in this case was considerably higher than in the old coal chute, and as 5 per cent was about the maximum grade up which cars could be pushed by the switch engine, the long trestle approach required a great deal of space.

To overcome this objection the approach was sometimes built with a 25 per cent grade and a small dummy car used to pull the cars of coal up to the unloading track. This dummy car would recede into a pit at the foot of the approach and when the

cars were placed ready to be brought up, the dummy would be pulled up back of them by a cable attached to a hoisting drum at the head of the trestle and take the cars up the grade.

95. Clam Shells.—Fig. 144 illustrates a Dodge standard-gauge steam-operated revolving locomotive crane arranged for handling ashes and coal. The portability of the crane permits a ready change to another coaling point in the yard, or to an entirely different city on the line if desired. Sometimes the coal is handled directly from the cars to the engine by the clam shell.



A. Cars Unloaded by Hand. *B*. Cars Unloaded by Gravity.

FIG. 143.—Coal Docks.

96. Mechanical Plants.—At terminals the space available is generally limited, or is so valuable that room cannot be had for the construction of a plant of the trestle type. Modern large coaling plants, therefore, are built so that the coal is elevated by machinery, although in some cases a locomotive crane is employed, as shown above, which loads directly from the cars to the tender.

The mechanical plants elevate the coal from a receiving hopper below the track by means of balanced buckets, or by a continuous elevator consisting of a series of small buckets. Fig. 145 illustrates a station using two balanced buckets to elevate

the coal. These plants are generally built of wood, although of recent years steel and also concrete stations have been constructed. It is very doubtful whether the extra expense of the concrete as compared to wood construction is entirely warranted for this purpose. The operating conditions change so rapidly on a rail-

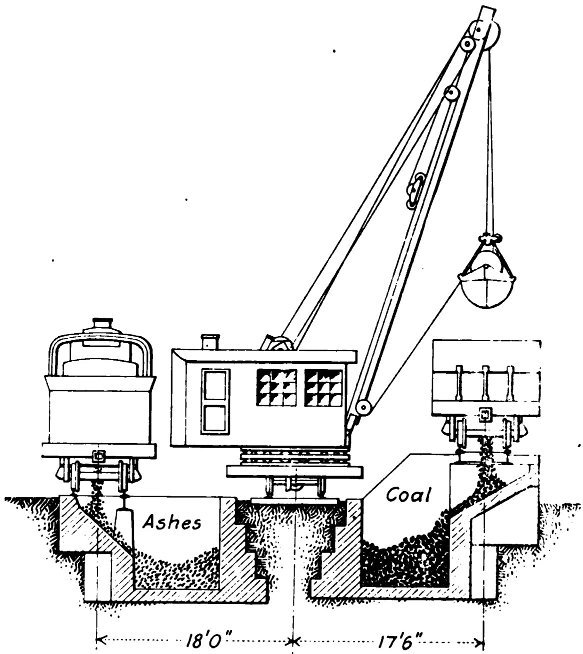


FIG. 144.—Clam Shell.

road that it is quite difficult and, in fact, almost impossible to forecast with any degree of accuracy what will be the requirements forty or fifty years hence. In many cases, even with the shorter-lived wooden station, it is necessary to take it down while still good for several years, on account of changed conditions which will not permit of its operation in the locality where it stands.

Fig. 146 presents examples of modern coaling stations. Fig 146*A* and *B* are Holmen balanced bucket plants. *A* is a vie of the same station that is shown in Fig. 145 and illustrates th use of concrete encased steel substructure with a frame co pocket. The storage capacity is 500 tons and the elevatin capacity 125 tons per hour. Steam power is used. The statio

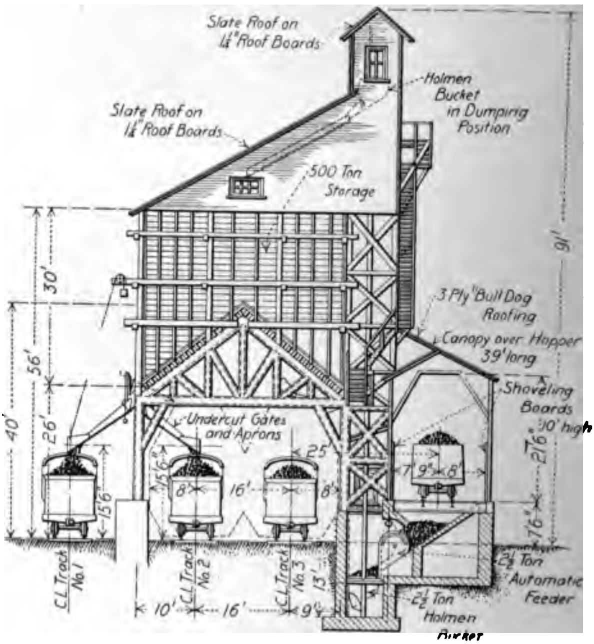


FIG. 145.—Holmen Balanced Bucket Coaling Station.

is located on the C. C. C. and St. L. Ry., at Greensburg, Ind Fig. 146*B* is a side view of a 100-ton steel station on the E. J and E. Ry., at Waukegan, Ill.

Fig. 146*C* is a reinforced-concrete locomotive coaling statio built by the Dodge Company for the Norfolk and Western Rail way at Hayesville, Ohio. This is an 880-ton pocket, with sand

A. Wood. (Holmen.)

B. Steel. (Holmen.)

C. Concrete. (Link Belt.)

FIG. 146.—Examples of Coaling Stations.

drying house, boiler-house and small overhead dry sand bin. The pocket is built over five tracks in three spans, two of which are main line tracks, two passing sidings, and one a coal-dumping track.

Records of the cost of handling coal at coaling plants on different roads vary widely on account of the methods employed in collecting figures. The operating cost of handling coal where self-cleaning cars are used should not exceed $.05 per ton, and may run considerably less than this under favorable conditions, many roads reporting less than $.03 per ton operating charges.

The use of weighing apparatus to determine the amount of coal delivered to each engine is not generally considered necessary, and many managers feel that the cost of equipping the stations with scales is not justified.

The self-cleaning cars used at mechanical plants during the winter months are very expensive to unload on account of the coal becoming frozen. To obviate this difficulty thawing plants, which consist of suitable insulated buildings containing one or more tracks, are used by some roads. The cars are run into these and the frozen coal is thawed out. The car is then taken to the coaling station and dumped. The record of the South Amboy thawing plant on the Pennsylvania (shown in Fig. 147) appears to justify fully the expense of the installation, owing to the cheap cost of unloading the coal in winter.

97. Storage of Coal.—In times of approaching scarcity of coal it is necessary to store sufficient amounts on the ground at convenient points to insure a continuous supply for the operation of the road. This is generally done by unloading the coal with a clam shell and picking it up when needed with a clam shell or steam shovel, loading it into cars and sending these to the different plants. On account of the large amounts of coal required by a railroad there has been a growing tendency on the part of the larger roads to establish storage grounds with permanent machinery for handling the coal, although the general practice at the present time is to use temporary storage near where the coal is to be used rather than have a permanent storage plant located at some central distributing point.

Fig. 148 shows the usual method employed for the temporary torage of coal on roads not equipped with permanent storage lants. The crane in the figure is the same as shown in Fig. 144, nd is used for this purpose as well as coaling engines.

Fig. 149 shows the Dodge System of coal storage. The plant llustrated in the view is installed for the Susquehanna Coal Co., t Old Bridge, N. J., and has a capacity of 210,000 tons, in four-

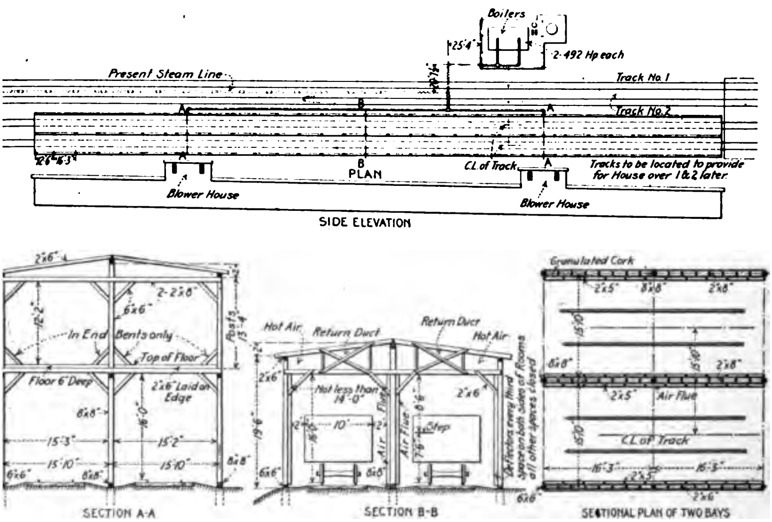


FIG. 147.—South Amboy Thawing Plant, Pennsylvania Railroad.

een piles, located on both sides of a central track system. The iew of the reloader shows the operator at the pivot about which he reloader revolves as it takes coal from the pile. The incline or taking coal to the tower for screening and delivery to cars ppears at the operator's left. The photograph of the reloading ower shows the shaking screen, delivery chute to the cars and eceiving bin for screenings.

As the railroads consume about one-fourth of all the coal nined and as their interest is not only that of a consumer but

of the carrier, the problem of equalizing the demand on the mines may well receive attention.

The losses of coal exposed to the weather is not as great as is commonly supposed. In their conclusions from tests on the weathering of coal Prof. S. W. Parr and W. F. Wheeler state:*

Coal of the type found in Illinois and neighboring States is not affected seriously during storage when only the change in weight and losses in heating power are considered. The changes in weight may be either

FIG. 148.—Storing Coal with Clam Shell. (Dodge.)

gains or losses of probably never over 2 per cent in a period of one year. The heating value decreases most rapidly during the first week after mining and continues to decrease more and more slowly for an indefinite time. In the coals that have been tested, 1 per cent is about the average loss for the first week and 3 to 3½ per cent would cover the losses for a year.

It should be observed, however, that bituminous coal will sack badly when exposed to the weather for periods exceeding two months. Apparently there is little danger from spontaneous combustion if the coal is in small piles, but in large units care

* Bulletin No. 38, University of Illinois, Eng. Exp. Station, 1909.

FIG. 149.—Dodge System of Coal Storage.

should be used to avoid heating. On the Central of Georg with bituminous coal of a fairly hard grade the storage piles ar about 15 ft. high, and no trouble from spontaneous combustio is experienced.

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CHAPTER XIII

SHOPS AND ENGINE HOUSES

98. Roundhouses.—In general a circular form of house with , turn-table in the center of the circle is to be preferred. A ;ood arrangement is shown in Fig. 150*B* of the Michigan Central ıouse.

A. View of Round House under Construction.

FIG. 150.—Round Houses.

This section is sometimes modified by having the roof slope oward the turn-table; this, however, drains the water toward he inner circle, which is an objectionable feature, as the roof ;utters may freeze up and the water instead of being carried off vill overflow where the engines enter the house.

The details of construction are of considerable importance, ,nd for the purpose of discussing these we may consider the oundhouse to be divided into: 1, foundations and pits; 2, the

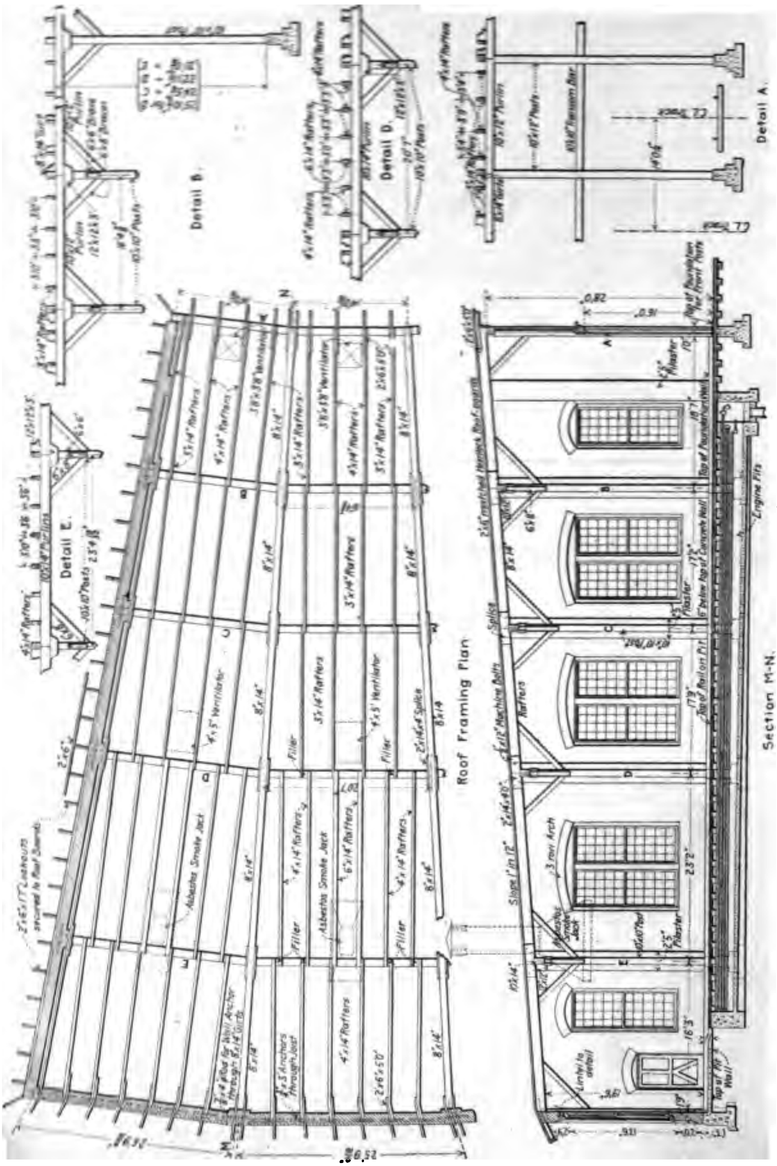
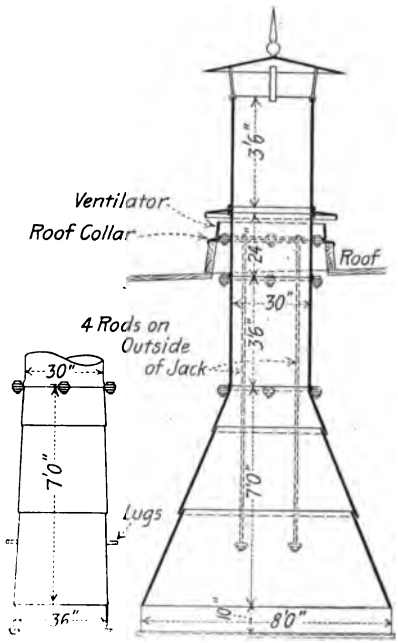


FIG. 150B.—General Arrangement of Michigan Central Round House.

roof; and 3, the walls, which will be considered in the order named.

For the foundations and pits concrete is generally used, and if it is necessary to employ a deep foundation to get solid ground the concrete may profitably be reinforced.



C. Smoke Jack. (Dickinson.)
FIG. 150.—Round House.

Steel, on account of the corrosion of this material, due to the engine gases, should not be used in the roof unless protected by concrete. Many engineers prefer the reinforced concrete roof to the wood roof on account of the fireproof construction obtained.

As much window space as possible should be allowed in the

walls. This leaves very little space to fill in except between tl window sill and the floor. Brick or concrete is generally us for the walls, although in a wooden house the walls may be bui of wood. The end walls and fire walls are usually built of tl same material as used for the outer walls.

The American Railway Engineering Association recommen the following:*

(*a*) The material used in construction should be non-corrosi unless proper care be taken to prevent corrosion.

(*b*) Reinforced concrete should be used below the floor when it cheaper than plain concrete

(*c*) The additional security against interruption to traffic fr fire warrants the serious consideration of the use of a reinforced co crete roof.

(*d*) When the roof is of reinforced concrete the columns should of the same material.

(*e*) Reinforced concrete should be used for the walls only where spec conditions reduce its cost considerably below that of brick or plain co crete.

On account of the large amount of smoke from the engin in the house, special provision has to be made to carry it to t outside air. This is done by placing a smoke jack (Fig. 150 in each stall, located so that the stack of the locomotive w come directly underneath the jack and very little of the smo will escape into the house. These jacks were formerly made wood, but on account of the danger from fire are now general of cast iron or some special material such as transite (an asbest compound) which will not catch fire from the sparks coming fr the engine.

99. Heating Plants.—In the heating of roundhouses, eith indirect hot-air heating, the low-pressure vacuum process steam heating or heating with high-pressure steam radiators employed.

When direct radiation is employed, either low or high pr sure, the coils are placed in the pits underneath the engines a along the outside walls of the house.

* Manual, 1911, p. 119.

In indirect heating or by means of air heated by passing over steam coils, the hot air is forced by a fan through ducts under the floor of the house with an outlet generally located in each pit. There is a great deal of difference of opinion as to the relative

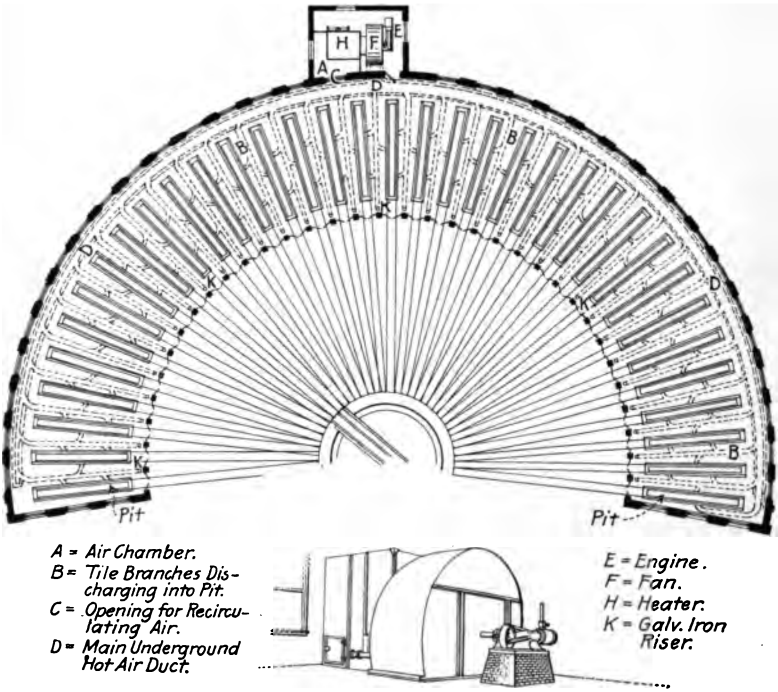


FIG. 151.—Arrangement of Indirect Radiation Heating System. (Am. Blower Co.)

merits of the direct and indirect methods of heating, and both are used extensively.

Fig. 151 shows the arrangement of ducts, heating coils, fan, etc., in a round house using indirect heating. The advocates of this system claim that much better ventilation is obtained, but it must be remembered that the air forced in through the air

ducts is not all fresh air but is mostly recirculated, and also that the natural circulation of air in the round house is quite rapid on account of the many openings required to carry off the smoke.

100. Turntables.—Fig. 152 shows an example of a turntable. The tractor by which the turntable is operated is shown to the left in Fig. 152*A*. Formerly all tables were turned by means of a long pole extending beyond the table which was pushed by a number of men, but with the introduction of heavier engines this became so difficult that air and electrical tractors are now used in nearly all cases. The air tractor, which is operated from the air pump of the locomotive standing on the turntable is shown in Fig. 152*B*. Turntables have increased in length very rapidly in the last few years to keep pace with the longer engines which they are required to carry and are now made 100 ft. long.

The Committee on Turntables of the American Railway Bridge and Building Association recommends that for standard gauge roads no future turntable be built shorter than 75 ft. and that for roads that expect to use the heaviest engines, 90 ft. be adopted as standard. For engines having wheel bases longer than 90 ft. wye tracks should be provided unless special local conditions compel the use and justify the expense of a longer table.

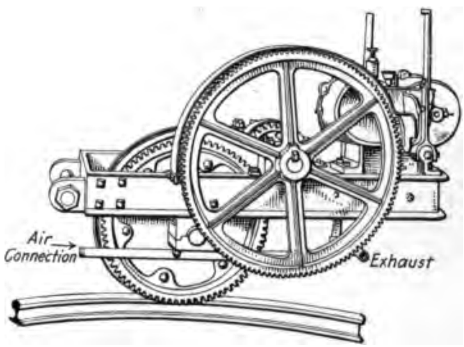
The Santa Fe does not turn its long Mallet engines on a turntable. Mr. A. F. Robinson, bridge engineer of the system, states that he is "not in favor of building extremely long turntables, that is, long enough to handle our double Mallet Santa Fe engine; a table to do this would have to be about 135 ft. in diameter. These can be built and operated successfully; the cost of repair and operation, however, would, in the writer's judgment, be high."*

The deck-plate girder type appears to be the most used where the necessary drainage can be obtained from the turn-table pit, but when a shallow pit is required through-plate girders, or pony trusses, are employed. The advantage of using through tables to raise the bottom of the pit is indicated by comparing

* Turntables, Proceedings Am. Ry. Bridge and Building Assn., 1912, p. 149.

the Pennsylvania 100-ft. deck turntable in which the depth from base of rail to top of catch basin is 11 ft. 2 ins. with the Norfolk and Western 100-ft. through turntable in which the depth is only 7 ft. 6 ins.

A. General View.



B. Air Tractor. (Detroit Hoist and Mach. Co)
Fig. 152.—Turntable.

The proper condition of a table depends largely upon the center upon which the table turns. A center composed of conical rollers is generally used, although many prominent roads use a disc center. The disc center represents the best

practice in draw-bridge design. The Burlington appears strongly to favor this type for their turntables, and a committee of the New York Central Lines which investigated the matter of centers recommended the use of disc centers.

101. Cinder Pits.—Before the engine enters the house the fire is drawn; this is done over a cinder pit, and the handling of the ashes from the fire is a matter of considerable importance.

FIG. 153.—Depressed Cinder Pit.

Until quite recently the most approved form of cinder pit was the depressed track shown in Fig. 153. A standard gauge track was located at the bottom of the pit and gondola cars were placed at the end of this track opposite the place where the ashes were dumped from the engines. The ashes were loaded into the car by hand.

An excellent type of mechanical cinder loader is shown in Fig. 154*A*. This consists of a small dummy car which is lowered

in a pit below the fire box of the engine and when full of ashes is hauled up a light steel track by a cable attached to an air plunger and unloads automatically into a car standing on an adjacent track to receive the ashes.

The automatic cinder pit, it will be observed, does away entirely with the depressed track for the gondola, and enables

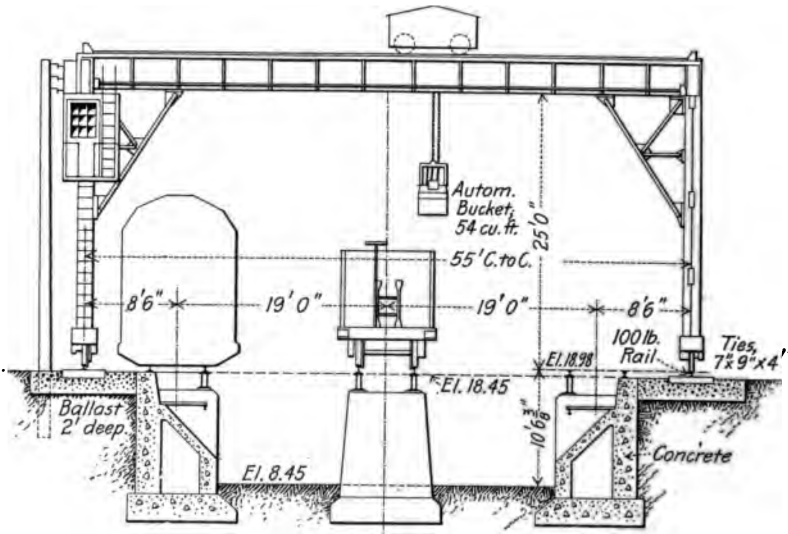
A. Robertson Cinder Conveyor.

FIG. 154.—Mechanical Cinder Plants.

the empty car to be spotted to receive the cinders by means of a pinch bar and without waiting for a switch to be made.

To handle ashes from the pit a gantry crane carrying an electrically operated grab bucket has been used on some roads; (see Fig. 154*B*.) Locomotive cranes are used in a somewhat similar manner.

102. Sand Houses.—Sand houses are provided at engine terminals to supply engines with sand. These are generally small wooden houses consisting of storage bins for the wet sand, a stove or steam pipes for drying the sand, means for elevating the sand by compressed air or hoisting mechanism and an elevated bin for the dry sand from which it flows to the engine through a spout. The sand house is usually located near and frequently



B. Gantry Crane at Gary, Ind., C. L. S. & E. Ry. (Am. Ry. B. & B. Assn.)
FIG. 154.—Mechanical Cinder Plants.

forms a part of the coaling plant, so the engines can take sand at the same time they are taking coal.

Fig. 155 shows an elevated tank for sand when the apparatus does not form part of the coaling-station building. The view shows as well the valve for controlling the flow of sand to the engine, the pneumatic sand hoist and the sand dryer. The sand tank is about 25 ft. above the track and the dry sand is

elevated into the tank through a 3-inch supply pipe. The sand dryer, which is a cast-iron stove surrounded with a perforated screen, has a capacity of from 10 to 20 cu.yds. per day.

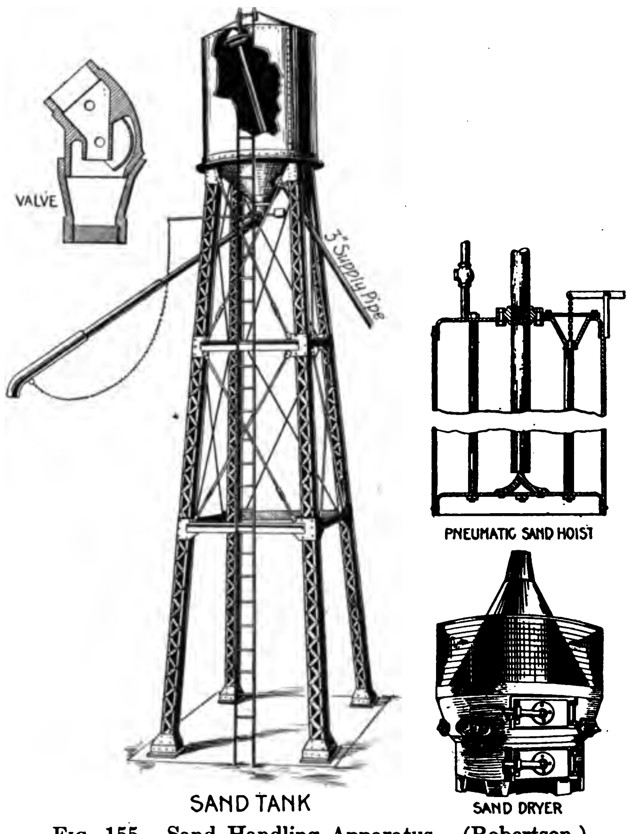


FIG. 155.—Sand Handling Apparatus. (Robertson.)

103. Shops.—Railroad shops are generally located at the divisional terminal point to take care of the local requirements, with the concentration, however, of all heavy repairs to equip-

ment both of cars and locomotives at a large central plant for the entire system, or for each grand division.

At the central plant the shop system may be divided into the following general classification:

Locomotive shops;
Freight-car shops;
Passenger-car shops.

These are supplemented by the blacksmith shop, boiler shop, foundry, planing mill, paint shop, store house and power plant.

The track layout may consist of cross tracks or longitudinal tracks running the length of the house.

In Fig. 156*A* the locomotive and boiler shops are served from a transfer table and the freight-car shop has longitudinal tracks running the length of the shop.* The locomotive erecting shop is generally provided with an overhead traveling crane.

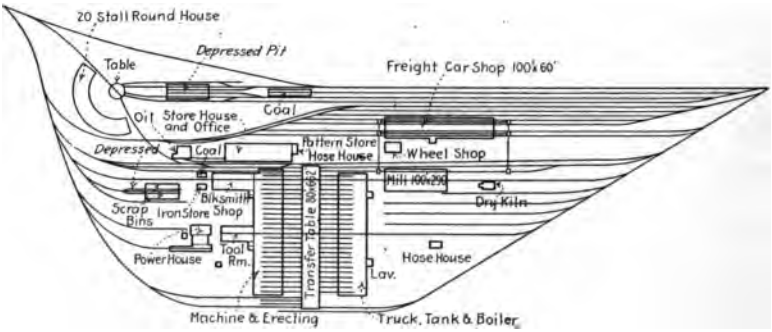
The use of cross tracks in connection with a heavy crane for traversing the locomotives is shown in Fig. 156*B*, which illustrates the Collinwood shops of the Lake Shore. The locomotives are turned on a turntable and enter the house on the center cross track from which they are handled by a traveling crane to the desired location.

It seems that for a division repair shop or general repair shop of a small road, the transfer table is generally preferred for a cross-erecting shop in connection with a light overhead crane, but at large shops the engines in most cases are transferred inside the building by a heavy overhead traveling crane. Recent practice, both in this country and abroad, appears to favor the cross shop rather than the longitudinal.

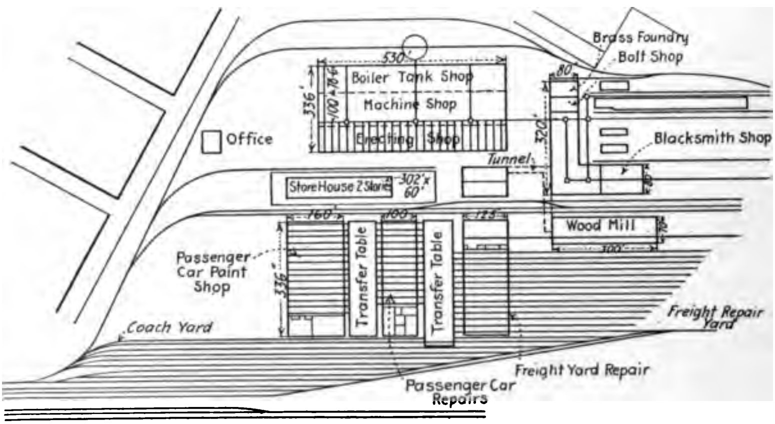
In the power house are located the boilers for heating the shops, the air compressors and the generators for supplying the electric current used for lighting and to operate the machinery in the different shops. The most modern practice is to use group drive, except in case of large machines, which are provided with separate motors.

* American Railway Shop Systems, W. G. Berg, 1904. The Railroad Gazette, New York, pp. 120, 142.

The shop buildings are one-story structures and may be built of either mill construction, structural steel or concrete. In their design careful attention should be given to the question of pro-



A. New York Central Shops, Oak Grove, Pa.



B. Lake Shore Shops, Collinwood, Ohio.

FIG. 156.—Layouts. (Berg.)

viding sufficient light, and saw-tooth roof construction should be used where practicable. Ample window space should be provided in the walls.

The floors in the blacksmith shop and foundry should be of cinders and in the other shops of wood, either planks on concrete or creosote block. The heating is generally by hot air, although in some plants hot water or steam is employed.

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CHAPTER XIV

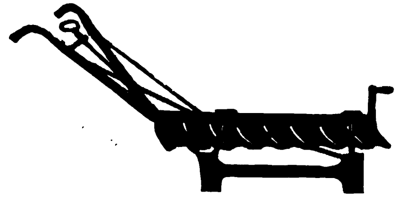
ICING STATIONS

104. Harvesting Natural Ice.—In cutting the ice the field is plowed with a special plow (Fig. 157) which cuts grooves in the ice about 22 ins. apart so as to divide the ice into squares 22 by 22 ins. The ice is broken up into cakes by sawing through the ends of a strip about 40 ft. long and adjacent to the clear water. The strip is then broken away from the remaining ice along the plowed grooves and floated down to the conveyor, Fig. 158, where a few strokes of the bars or spuds is sufficient to separate it into square cakes.

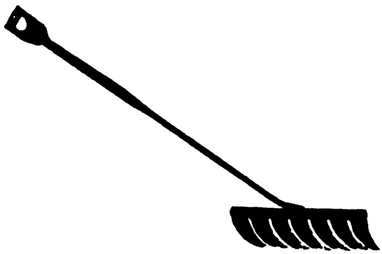
The conveyor handles the ice directly to the house, if it is located at the water, or onto a platform for loading into cars.

The ice may be fed straight into the end of the machine or the channel may be arranged for side feed, as shown in the illustration, Fig. 158*A*. The cakes are floated through the channel into the water box where the ascending bars engage the blocks from below, carry them up the incline and onto and along the adjustable gallery passing the room doors. At each door a man upon the gallery removes a certain number of cakes from the chain to the house run. As the house is filled the gallery is correspondingly raised by means of gallery hoists and at the end of the harvesting season the platform is at the top and remains in this position during the summer, leaving the front of the house free for the use of lowering machines to take the ice out of the rooms.

Fig. 158*B* shows a loading conveyor, which, as its name implies, is used where ice is taken direct from the water and transported some distance by rail to a house more or less remote from the source of supply. The blocks of ice, as shown in the



Plow with Swing Guide.



Hand Plow.

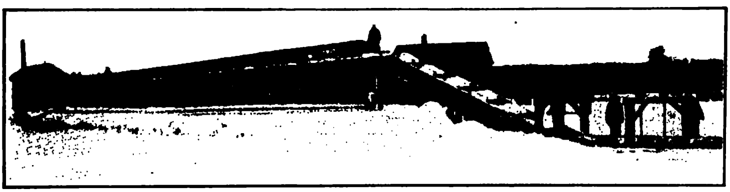
Splitting Bar.

Fig. 157.—Ice-cutting Tools. (Gifford-Wood.)

illustration, are forced straight into the apron of the machine and are caught by the bars and pass along the apron and up the incline to the car-loading platform.

The length of the car-loading platform is determined by the number of cars it is desired to load without switching. To

A. Elevator Conveyor. (Caldwell.)



B. Car Loader Conveyor. (Caldwell.)
Fig. 158.—Harvesting Ice.

facilitate the work the platform is generally placed between two side tracks, so that the loaded cars on one side may be pulled out and replaced by empties while the loaders are filling those on the other track.

105. Manufacture of Ice.—Generally speaking, the manufacture of ice at the icing station is not an economic proposition except in those localities where natural ice is not available in sufficent quantities. In the Northern States it costs only about $0.75 a ton to put the ice in the house, and even under the most favorable conditions ice cannot be manufactured for less than $1.25 to $1.50 per ton including all the charges at the plant.

The cost of manufacturing ice with electric drive in a 20-ton plant is about $1.40 per ton, assuming the plant to run 24 hours per day and 300 days per year, or 6000 tons per annum. The following estimate is given by Orrock:*

Approximate cost of installation:		
Machine shop and ice house		$4,000.00
Foundations		500.00
Water pipes and connections		500.00
Motor, compressors, condenser, ice tank with cans, coils, ice lift, etc., including insulation and all connections, erected complete		19,533.00
		$24,533.00
Distilling apparatus, if steam can be furnished		2,500.00
		$27,033.00
Supervision and contingencies, 10 per cent		2,767.00
		$29,800.00
Approximate cost of operating electric plant:		
$29,800.00 at 6 per cent		$1,788.00
Electric power, 60 H.P. at $40 per year		2,400.00
2 engineers at $2.50	$5.00	
2 ice men at $2.00	4.00	
Oil and waste	1.00	
Depreciation, repairs and incidentals	4.00	
	$14.00×300 days	4,200.00
Total		$8,388.00

or $1.40 per ton.

* Railroad Structures and Estimates, p. 139.

It should be observed that in comparing this price with the cost of natural ice, something should be allowed for the greater storage space required, and the loss due to shrinkage when natural ice is used.

Where electrical energy is cheap or if gas or oil engines are employed, raw water or a combination of raw and distilled water is used for making the ice. Where raw water is used, agitation of the water must be secured, which is usually done by stirring, or the injection of compressed air at low pressure.

106. Insulation.—It is evident that the function of an ice house is to prevent the outside heat in summer from passing into the interior of the house and melting the ice. The problem, therefore, is to interpose in the walls a material or a construction which will diminish the passage of heat, not necessarily to a minimum, but in such a degree that the sum of the fixed charges and the direct loss due to meltage results in the smallest amount for the given locality.

The selection of the proper construction in any case depends then upon:

1. The cost of the ice;
2. The temperatures encountered;
3. The cost of the insulation, and
4. The amount of heat it will admit into the house.

It is very apparent that a form of construction that would be economical for one of the Pacific Fruit Express Company's houses in California, where the first cost of ice is high, and the temperature in the summer often averages 120 degrees throughout seven or eight hours of the day, would prove undesirable for use under conditions affecting the ice houses in Michigan.

The cost of the ice and of the construction to be used for the house can be accurately calculated for any case under consideration. The average temperature outside of the ice house can be readily obtained from consulting the weather reports. It is, however, in determining the insulating value of the material or construction to be used that we find the greatest difficulty.

A great many tests have been made on insulating material, but before attempting to apply the results obtained from these

tests it will be necessary first to review the general principles affecting the transmission of heat through ice-house insulation.

Fig. 159 shows a section of wall composed of only one material, as a brick wall. If the house is filled with ice we will find during the summer months a continuous flow of heat from the outside of the wall to the inside. The inner surface of the wall will be warmer than the air within the house on account of the difficulty the heat finds in leaving this surface.

Heat is taken from the wall on the inside of the house in two ways: by radiation and by air contact. The radiated heat travels through the air with very little heating, but the heat lost by air contact or convection actually heats the air next the surface. The reverse of this condition applies to the outer wall surface. This surface is cooler than the outside air and absorbs the heat by radiation and by contact with the warm air. In the case of the outer wall a descending current of air is found, but on the inner surface the current of air ascends.

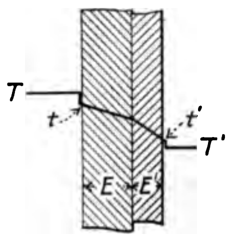


Fig. 159.—Flow of Heat through Simple Wall. (After Paulding.)

Within the wall the heat passes uniformly from one surface to the other, due to the conductivity of the material of which the wall is composed.

We may assume that the radiation is proportional to the difference of temperature existing in the wall and the objects radiated to. Table XVIII gives this value for different materials. In the Table, K represents the B.T.U. radiated per hour per square foot per one degree difference of temperature between the temperature of the surface and the temperature of the objects radiated to.

TABLE XVIII

Radiation of Heat

Values of K for Different Surfaces
(Péclet, Traité de la Chaleur)

Oil paint	.759	Plaster and brick	.737
Paper	.772	Wood	.737
Building stone	.737	Sheet iron	.567

For example, a painted inner wall, which is 3 degrees cooler than the object radiating heat to it, would absorb $3 \times .759 = 2.28$ B.T.U. per hour a square foot.

Table XIX shows the loss of heat from air contact. This is the same for different materials, but varies with the difference in temperature between the material of the wall and the surrounding air and with the heat of the wall. For example, if the wall is 30 ft. high and the difference in temperature between the wall and the air is 3 degrees, then the heat absorbed per square foot per hour would be $.27 \times 3 = .81$ B.T.U.

TABLE XIX

LOSS OF HEAT FROM AIR CONTACT

Values of K' for a Plane Vertical Wall in B.T.U. per hour per square foot per one degree difference of temperature of wall-surface and surrounding air.

Height of Wall in Feet.	Value of K'.
1	.40
2	.35
4	.32
8	.30
16	.28
32	.27
64	.26

The quantity of the heat transmitted through the insulation from outer surface to inner surface varies directly as the area of the wall, directly as the conductivity of the material, inversely as its thickness, and directly as the difference of temperature between the two surfaces.

The formula for an area of 1 sq.ft. of a homogeneous wall with plane parallel surfaces is then *

$$M = \frac{C(t-t')}{E},$$

* For derivation of formulæ see Paulding's treatise, Transmission of Heat through Cold-Storage Insulation, 1905, D. Van Nostrand, New York.

The floors in the blacksmith shop and foundry should be of cinders and in the other shops of wood, either planks on concrete or creosote block. The heating is generally by hot air, although in some plants hot water or steam is employed.

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SHOPS

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The formula for the homogeneous wall shown in Fig. 159 is

$$M=\frac{CQ(T-T')}{2C+QE}, \quad \ldots \ldots \quad (1)$$

in which

M = B.T.U. transmitted per hour per 1 sq.ft.;
C = The conductivity of material;
$Q=K+K'$;
E = The thickness of the wall in inches;
T = The temperature of the outer air;
T' = The temperature of the inner air.

In finding Q it is best to take for K and K' averages of the values appropriate for the inner and outer walls, where, as generally happens, these values are different.

The formula for the compound wall shown in Fig. 160 is

$$M=\frac{Q(T-T')}{2+Q\left(\frac{E}{C}+\frac{E'}{C'}\right)}, \quad \ldots \ldots \quad (2)$$

and for a wall made up of any number of layers of different materials we would have

$$M=\frac{Q(T-T')}{2+Q\left(\frac{E}{C}+\frac{E'}{C'}+\frac{E''}{C''}+\ldots\right)} \quad \ldots \ldots \quad (3)$$

in which

M = B.T.U. transmitted per hour per 1 sq.ft.;
C, C', C'' = The respective conductivities of the different layers;
$Q=K+K'$;
E, E', E'' = The respective thickness in inches of the different layers;
T = The temperature of the outer air;
T' = The temperature of the inner air.

For an example take the wall shown in Fig. 161. This consists of an outer layer of $\frac{7}{8}$-in. tongued-and-grooved spruce sheathing (conductivity .93), then a layer of waterproof paper about .03 in. thick (conductivity .27), then $1\frac{1}{2}$ ins. of hair-felt (conductivity .32), then paper, spruce, paper, hair-felt, paper, spruce and galvanized iron.

On account of the ease with which it transmits heat, we may pay no attention to the galvanized iron, except to choose a value of K midway between that due to the iron (.57) and that due to the outer painted surface (.76).

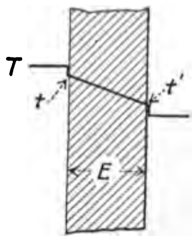


FIG. 160.—Flow of Heat through Composite Wall. (After Paulding.)

FIG. 161.—Wall Composed of Boards and Hair Insulation. (After Paulding.)

Let us suppose the height of the wall to be 10 ft. Then $Q=30+\frac{1}{2}(.57+.76)=.97$.

Let the temperature of the outer air be 90 degrees and that of the inner 20 degrees. Then by formula (3) we have

$$M=\frac{.97(90-20)}{2+.97\left[3\times\frac{.875}{.93}+4\times\frac{.03}{.27}+2\times\frac{1.5}{.32}\right]}=4.8.$$

The formula for a wall containing air spaces is as follows:

$$M=\frac{Q(T-T')}{2+Q\left[\frac{E}{C}+\frac{1}{Q}+\frac{E'}{C'}+\frac{1}{Q}+\frac{E''}{C''}+\ \ldots\ .\right]}, \quad . \quad . \quad . \quad (4)$$

For the notations see equation (3).

As a numerical example we may suppose in Fig. 161 the hair-felt to be removed, leaving two air-spaces, but all other conditions of the example remaining unchanged. In the formula then we drop out the term representing the hair-felt and substitute the value of $\frac{1}{Q}$, which in this case would be

$$\frac{1}{.30+.77}=\frac{1}{1.07}$$

and

$$M=\frac{.97(90-20)}{2+.97\left[3\times\frac{.875}{.93}+4\times\frac{.03}{.27}+2\times\frac{1}{1.07}\right]}=9.7.$$

We have in this case practically doubled the transmission by substituting air-spaces for hair-felt.

Paulding states that:*

> Experiments have repeatedly shown that the thickness of the air-space is of no effect for ordinary thicknesses. Taking one inch as a practical thickness for ordinary construction, and the value of $\frac{1}{Q}$, lying very near to unity, for a material to be of the same value as the air-space, $\frac{C}{E}$ must equal unity, and for the same thickness, namely one inch, C must equal unity. This is about true for ordinary spruce; for almost any of the other materials used in insulation the air-space would be a disadvantage in a wall of fixed thickness. Of course an added air-space that does not displace any insulating material is always a help, but space is frequently too valuable for this construction to be used.

Mr. G. H. Stoddard has made some interesting experiments for the purpose of demonstrating the value of successive air-space.†

* Transmission of Heat through Cold Storage Insulation, C. P. Paulding, 1905, D. Van Nostrand Co., New York, p. 26.

† Paper on Insulation, Eleventh Annual Convention of the American Warehousemen's Association. See Ice and Refrigeration, November, 1901.

Mr. Stoddard deduces from these experiments that for the purpose of insulation

a wide air-space has no greater value than a narrow one, and that any space over one-half (½) inch in width, if it can be kept dry, will be of greater value if filled with an insulating material as good as mill shavings than if left as an air space.

The reason that air spaces are not efficient methods of insulation is that while still air will allow very little heat to pass through it, it never remains still, but is constantly in motion and thus carries the heat by convection, as shown in Fig. 162. It will be seen, therefore, that unless the air is confined in very small spaces it loses much of its insulating properties. Most of the insulating materials now in use are those in which a large volume of air is enmeshed.

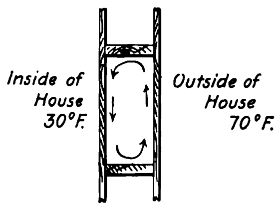


FIG. 162.—Heat Carried by Convection.

The first material which was used extensively in ice-house insulation was sawdust, but this is now generally condemned, as its insulating value is rapidly lost, due to the absorption of moisture. It tends to cause rotting of the wall and under certain conditions is liable to spontaneous combustion.

Planing mill shavings, which should be packed about 9 lbs. to the cubic foot, are better than sawdust; but the tendency in modern ice-house construction is to use a higher grade of insulating material.

Mineral wool is manufactured from silica-bearing limestone rock. The broken rock is melted in cupolas at a temperature of about 3500° F. and as the molten liquid rock leaves the mouth of the cupola it is met by a steam blast which expands it into fine silken threads. These threads are blown through oil vapor which renders the wool soft and pliable and removes dust and shot. Mineral wool resembles bulk cotton in appearance.

Mineral wool when properly tamped in place weighs 14 lbs. to the cubic foot. It is packed in bags containing 50 lbs.

Regranulated cork is a by-product. In the manufacture of corkboard, pure granulated cork is slightly compressed and then baked in molds of proper shape and size. As the boards come from the molds, they are trimmed to accurate dimensions. The sawings and trimmings are reduced again to a granulated state and the resulting product called regranulated cork.

Regranulated cork is dark brown in color and is manufactured in two grades, known as fine regranulated and coarse regranulated, respectively. Since it is a by-product, it cannot be supplied in unlimited quantities, although generally a stock sufficient to fill an ordinary order is available. Fine regranulated cork, when properly tamped, weighs approximately $7\frac{1}{2}$ lbs. to the cubic foot. The size of the granules ranges from about a half a wheat grain to very fine.

Coarse regranulated cork, properly tamped, weighs approximately $6\frac{1}{2}$ lbs. to the cubic foot. The size of the granules ranges from a small pea to a wheat grain.

Both coarse and fine regranulated cork are packed in bags holding from 40 to 50 lbs.

Granulated cork is cut from raw cork stock and can be furnished in almost any size. The size generally used is called unscreened granulated. The granules vary in size from $\frac{1}{2}$ in. in diameter to fine. The difference in the size of granules causes this size to pack well without leaving large air voids.

Hair is used extensively for insulating purposes; this is in the form of a quilt $\frac{1}{4}$ or $\frac{1}{2}$ in. in thickness with a layer of waterproof paper on either side. Linofelt, composed of flax fiber, is also used in the same manner.

Most insulating materials are considerably affected by the presence of moisture, and the use of paper in ice-house walls is therefore valuable. In addition to preventing the entrance of moisture, the paper increases the insulating value of the wall by changing the density of the material as many times as possible without adding to the thickness of the wall. Professor Tyndall has shown that this is an important feature in retarding the passage of heat. The paper *per se* has very little to do with insulating the wall, but in changing the density of the

medium and in keeping out moisture and air it is of prime importance.

Before passing to a consideration of the design of the ice house, let us examine the more recent experiments on insulation. The most valuable tests are those made on different insulations as a whole, and not the filling material alone. In Table XXI are presented the results of tests gathered from different authorities. In the last column is given the value of the different insulations as calculated by formulæ 3 and 4. To anyone familiar with the difficulties of tests of this kind the agreement between theory and tests will prove quite satisfactory.

The value as given by tests are reported by Cooper.* Starr's tests were presented in a paper read before the eleventh annual convention of the American Warehousemen's Association, in October, 1901. The tests of the Nonpareil Cork Manufacturing Co. were made with their own apparatus, comparing their material for the most part, with wood board and air-space construction. Cooper's tests were not made in the interest of any particular company, but were for the purpose of determining the value of air-space construction as compared with filled spaces and sheet material.

Formulæ Nos. 3 and 4 are applicable to floors and ceilings, except for the coefficient K'; but it will be observed that the carrying of heat by convection, represented by this coefficient, while lower for the ceiling than in the case of a vertical wall, is obviously much higher for the floor, and it is probable that in most cases the average value of K' is not far from that given in Table XIX.

107. Buildings for Storing Ice.—Fig. 163 shows a typical construction for a small ice house. Here the roof seems to be faulty, inasmuch as there are openings to the outer air direct from the space in which ice is stored. This arrangement is undesirable, especially if there are any leaks through which air can pass around the walls close to the foundation, and these leaks are nearly always to be found.

The result is a slow, but continuous circulation; the cold

* Practical Cold Storage, 1914, Nickerson & Collins, Chicago, p. 103.

TABLE XXI

Tests on Different Types of Insulation

(Results of tests taken from Practical Cold Storage.)

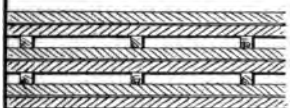
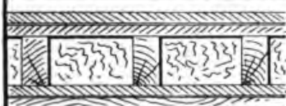
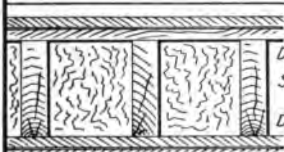
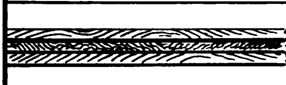
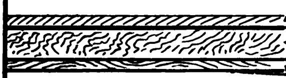
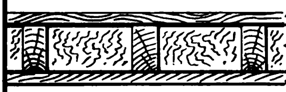
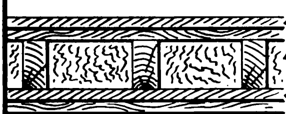
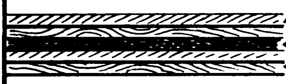
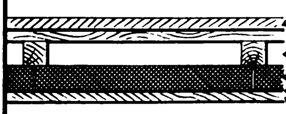
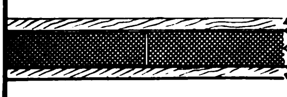
	B.T.U. Transmitted per sq. ft. per Day per Degree of Difference of Temperature.				
	Test.				Calculations
Boards and Paper.	Cooper	Starr	Nonpareil Cork Mfg. Co.	Stoddard	
 4, $\frac{7}{8}$" Spruce Boards. W.P. Paper		4.28	4.75		4.1
 $\frac{7}{8}$" Boards and W.P. Paper. 1" Air Space. $\frac{7}{8}$" Boards and W.P. Paper.		3.71	4.25	3.36	3.5
 $\frac{7}{8}$" Boards and W.P. Paper with 1" Air Spaces.		3.15	3.45	2.30	2.5
Mill Shavings.					
 $\frac{7}{8}$" Board, W.P. Paper, 4" Mill Shavings, W.P. Paper, $\frac{7}{8}$" Board	2.95				2.38
 $\frac{7}{8}$" Boards and W.P Paper, 4" Mill Shavings, $\frac{7}{8}$" D.&M. Boards and W.P Paper	2.61			1.80	2.00
 $\frac{7}{8}$" Boards and W.P. Paper, 8" Mill Shavings: Dry / Slightly Moist / Damp, $\frac{7}{8}$" Boards and W.P. Paper		1.35 1.80 2.10		1.15	1.32
Same with 12" Mill Shavings				0.86	0.98
" " 16" " "				0.67	0.78
" " 20" " "				0.55	0.65
" " 24" " "				0.48	0.56

TABLE XXI—(*Con.*)

	B.T.U. Transmitted per sq. ft. per Day per Degree of Difference of Temperature.				
	Test				Calculations
Hair Felt.	Cooper	Starr	Nonpareil Cork Mfg. Co.	Stoddard	
7/8" Board; W.P. Paper; 1" Hair Felt; W.P. Paper; 7/8" Board	4.91				3.47
7/8" Boards and W.P. Paper; 1" Hair Felt; 7/8" Boards and W.P. Paper		3.32			2.67
7/8" Board; W.P. Paper; 3" Hair Felt; W.P. Paper; 7/8" Board	1.88				1.82
Cork.					
7/8" Board; W.P. Paper; 1" Cork; W.P. Paper; 7/8" Board			4.20		4.03
7/8" Board; W.P. Paper; 2" Cork; W.P. Paper; 7/8" Board		3.25	3.24		3.02
7/8" Board; W.P. Paper; 3" Cork; W.P. Paper; 7/8" Board	3.11	2.10	2.25		2.40
7/8" Boards and W.P. Paper; 1" Cork; 7/8" Boards and W.P. Paper		3.30	3.10		3.07
7/8" Boards and W.P. Paper; 4" Cork; 7/8" Boards and W.P. Paper		1.70			1.74

TABLE XXI—(*Con.*)

	B.T.U. Transmitted per sq. ft. per Day per Degree of Difference of Temperature.				
	Test.				Calculations
Mineral Wool.	Cooper	Starr	Nonpareil Cork Mfg. Co.		
		4.60			4.51
		3.62			3.28
	3.48				2.59
			2.20		2.14
Lith and Linofelt. 		2.30			2.62
		1.79			1.72
		1.59			1.50

For an example take the wall shown in Fig. 161. This consists of an outer layer of $\frac{7}{8}$-in. tongued-and-grooved spruce sheathing (conductivity .93), then a layer of waterproof paper about .03 in. thick (conductivity .27), then $1\frac{1}{2}$ ins. of hair-felt (conductivity .32), then paper, spruce, paper, hair-felt, paper, spruce and galvanized iron.

On account of the ease with which it transmits heat, we may pay no attention to the galvanized iron, except to choose a value of K midway between that due to the iron (.57) and that due to the outer painted surface (.76).

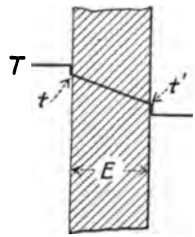


FIG. 160.—Flow of Heat through Composite Wall. (After Paulding.)

FIG. 161.—Wall Composed of Boards and Hair Insulation. (After Paulding.)

Let us suppose the height of the wall to be 10 ft. Then $Q=30+\frac{1}{2}(.57+.76)=.97$.

Let the temperature of the outer air be 90 degrees and that of the inner 20 degrees. Then by formula (3) we have

$$M=\frac{.97(90-20)}{2+.97\left[3\times\frac{.875}{.93}+4\times\frac{.03}{.27}+2\times\frac{1.5}{.32}\right]}=4.8.$$

The formula for a wall containing air spaces is as follows:

$$M=\frac{Q(T-T')}{2+Q\left[\frac{E}{C}+\frac{1}{Q}+\frac{E'}{C'}+\frac{1}{Q}+\frac{E''}{C''}+\ \dots\ \right]}, \quad . \quad . \quad . \quad (4)$$

would therefore, oppose the passage of heat, until the heat leaking in through the exterior wall raised the temperature of this air quite appreciably.

Where the air space is open, however, it is found that the result is to supply a continuous current of heat which must be taken up by the wall structure and hence transmitted into the ice chamber. The lower portion of the air in the circulating air chamber is cold and the upper portion warm. If the circulation is brisk, the cold air will leak out at the bottom and be replaced by warm air from above. This warm air is in turn cooled, and this cooling effect means ice meltage.

The use of sawdust as previously noted should be discouraged, While at first this type of construction has a satisfactory insulating value as soon as the sawdust becomes damp, as it undoubtedly will, the heat transmission through the walls will become continuously higher because damp sawdust has two or three times the heat transmission of dry sawdust. The dampness is due to the depositing of moisture on the walls from the air within the room, the dampness penetrating the filling, and the ice waste grows larger from year to year.

Fig. 164 illustrates the typical wall construction used in the Swift Company houses. It will be seen at once that this design possesses some very meritorious features. The free use of paper keeps the moisture from entering the wall and adds greatly to the insulating value by lamination. Formerly this company favored the use of sawdust filling, and its houses until quite a recent date have been sawdust filled. This filling is being removed as rapidly as possible in existing structures and replaced with mill shavings, which is likewise used in all new construction.

The Engineering Department of this company are very strenuously opposed to the practice of placing a ceiling over the ice. They apparently appreciate the value of preventing the air from reaching the ice, but believe that this is possible by using a top covering of 3 or 4 ft. of marsh hay. When the ice is being taken out, the hay is cast in racks or mangers provided for this purpose under the roof and thus kept dry. Ample air

Mr. Stoddard deduces from these experiments that for the purpose of insulation

a wide air-space has no greater value than a narrow one, and that any space over one-half (½) inch in width, if it can be kept dry, will be of greater value if filled with an insulating material as good as mill shavings than if left as an air space.

The reason that air spaces are not efficient methods of insulation is that while still air will allow very little heat to pass through it, it never remains still, but is constantly in motion and thus carries the heat by convection, as shown in Fig. 162. It will be seen, therefore, that unless the air is confined in very small spaces it loses much of its insulating properties. Most of the insulating materials now in use are those in which a large volume of air is enmeshed.

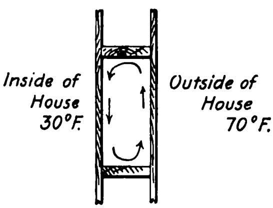


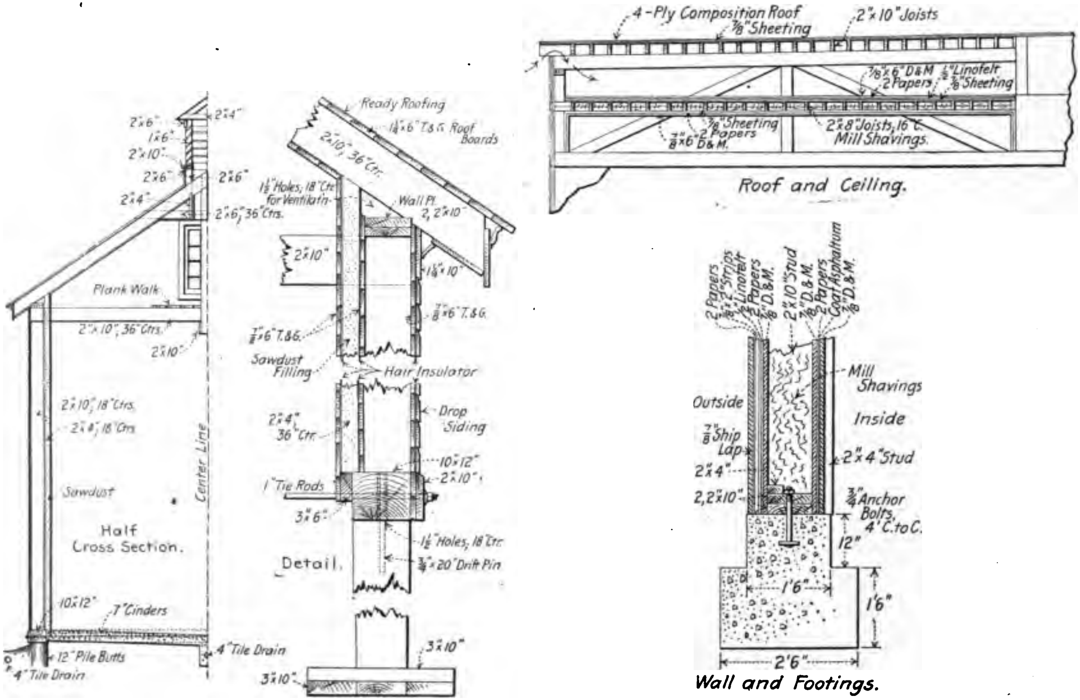
FIG. 162.—Heat Carried by Convection.

The first material which was used extensively in ice-house insulation was sawdust, but this is now generally condemned, as its insulating value is rapidly lost, due to the absorption of moisture. It tends to cause rotting of the wall and under certain conditions is liable to spontaneous combustion.

Planing mill shavings, which should be packed about 9 lbs. to the cubic foot, are better than sawdust; but the tendency in modern ice-house construction is to use a higher grade of insulating material.

Mineral wool is manufactured from silica-bearing limestone rock. The broken rock is melted in cupolas at a temperature of about 3500° F. and as the molten liquid rock leaves the mouth of the cupola it is met by a steam blast which expands it into fine silken threads. These threads are blown through oil vapor which renders the wool soft and pliable and removes dust and shot. Mineral wool resembles bulk cotton in appearance.

Mineral wool when properly tamped in place weighs 14 lbs. to the cubic foot. It is packed in bags containing 50 lbs.



A. House Using Hair Insulation. *B*. Cudahy House, Seymour Lake.

FIG. 165.—Ice House with Hair and Linofelt Insulation.

but

	C	E/C
$\frac{7}{8}''$ Board	.93	.94
0.2″ Hair	.32	.62
4″ Sawdust, slightly damp	1.00	4.00

and

$$24M=\frac{24\times 1.02\times 25}{2+1.02\left[4\times .94+3\times .62+4+\frac{1}{1.02}\right]}=48\text{ B.T.U.}$$

Multiplying this by the square feet of wall surface and by 100 days and dividing by 288,000 the number of B.T.U. required to melt 1 ton of ice will give the tons of ice melted due to the heat admitted through the walls. In estimating the capacity of the house 1 cu.ft. of ice is generally taken as weighing 50 lbs. or 40 cu.ft. for each ton of capacity.

Fig. 165*B* illustrates the insulation in the Seymour Lake houses of the Cudahy Packing Company near South Omaha, Neb. They state that these houses after being in use two years showed a shrinkage of less than 5 per cent.

An examination of the views given in the figure shows a considerable departure from the insulating methods of the preceding examples. Here we have the ice chamber protected by a well-insulated ceiling between which and the roof covering there is a suitable air-space provided with means for circulating the air. A waterproofing coat is put next the inside boarding of the house which prevents moisture reaching the wall and lowering its insulation value. In the wall is placed a ½-in. Linofelt covering.

The method of insulation used in the Galesburg ice house of the Chicago, Burlington and Quincy Ry., is shown by Fig. 166. This design was adopted only after a very exhaustive examination of existing structures throughout the country and has been frequently referred to in the technical press as representing the best modern practice in ice-house construction.

The shrinkage in this house is about 10 per cent, which includes as well the loss in crushing the ice and handling to the refrigerators.

Examining the insulating value of this house we find for the walls.

$$24M=\frac{612}{2+1.02\left(.81+4\times.87+8\times.11+8.00+8.00+\dfrac{1}{1.02}\right)}$$

$$=25 \text{ B.T.U.}$$

		C	E/C
$\frac{3}{4}''$	Boards	.93	.81
$\frac{13}{16}''$	Boards	.93	.87
.03″	Paper	.27	.11
2″	Lith	.25	8.00
6″	Sawdust, nearly dry	.75	8.00

Ceiling,

$$24M=\frac{612}{2+1.02\left(3\times.87+\dfrac{12}{.85}\right)}=32 \text{ B.T.U.}$$

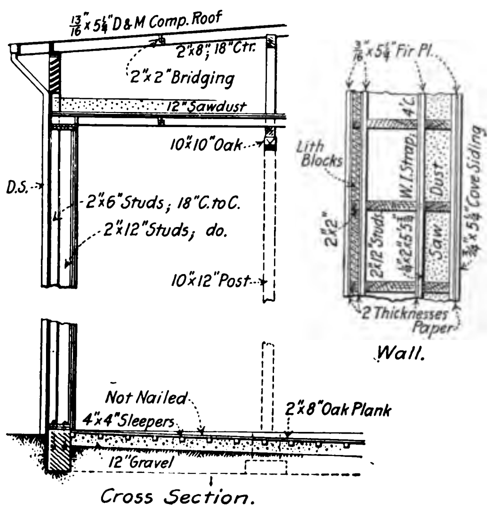


FIG. 166.—Ice House with Mineral Wool Insulation, C. B. & Q. House, Galesburg.

Figs. 147 and 167 show examples of cork insulation. In Fig. 147, the drawing illustrates the wall section of a house for thawing coal, but the method of construction is much the same as that used for an ice-house wall. Granulated cork is used which is tamped until it is of the required density. As the cork is a by-product in the manufacture of cork-board, it is much cheaper than cork-board insulation.

Fig. 167 presents the insulation used in the Illinois Central houses. Here, in addition to the cork, flax quilt and paper are employed and the inside of the house is plastered.

The best shape for an ice house, other things being equal, is that which will give the maximum cubic capacity for the minimum wall area. This is found in a cube, and therefore the more nearly square an ice house can be built, the smaller the wall space that has to be insulated, and the smaller will be the shrinkage. The whole trend of modern construction is toward the use of a flat roof supported by longitudinal trusses resting on the partition walls between the rooms; this enables any width of house to be used. The cost of the flat roof is probably a little less than that of the gable roof.

The Galesburg house on the C. B. & Q. Ry., is 81 ft. wide and the Collinwood house on the Lake Shore which was built by Swift & Company is 91 ft. 6 ins.

Concrete construction costs about 20 per cent more than a wooden house. Its principal advantage is its longer life, but the extra cost does not appear to be warranted for the reason that changes in the operation of the road may necessitate moving the house before the period of its natural life has been reached. Concrete has, however, been used, notably in the case of the recently constructed ice house on the Northern Pacific at Pasco, Wash., and also for some of the pre-cooling stations in California.

These pre-cooling stations lower the temperature of the cars before the ice is put in the tanks, and in warm climates are very effective in reducing the ice meltage on the first stage of the car's journey.

108. Delivering Ice to Cars.—The method formerly employed at large icing stations of crushing the ice on the platform and

shoveling it into the cars not only results in a heavy labor cost, but is extremely wasteful of the ice as well. All modern plants

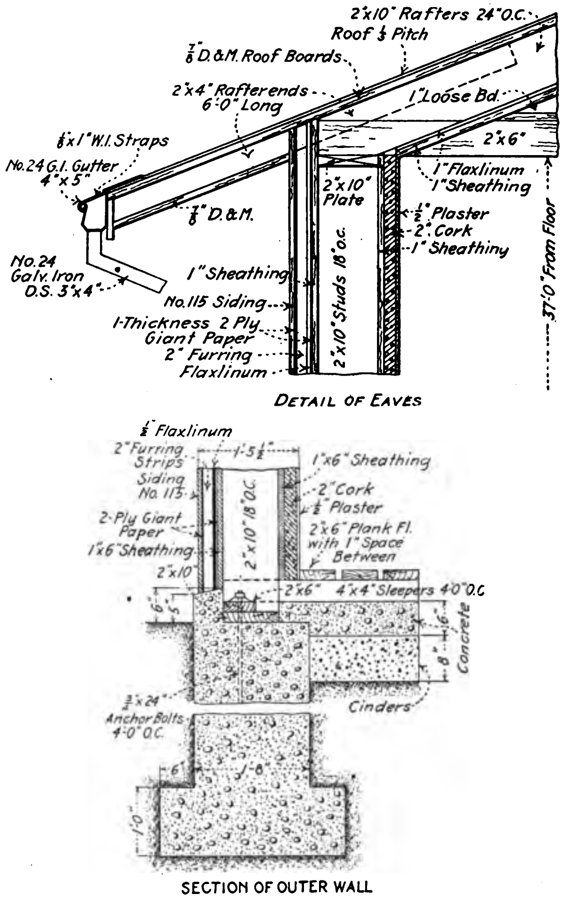


FIG. 167.—Ice House with Cork Insulation, Illinois Central House.

employ a crusher to prepare the ice for the refrigerator cars used in beef or poultry service; the cake ice for the fruit and butter

and eggs is, however, skidded along a platform approximately level with the top of the cars.

Fig. 168 illustrates the Galesburg house on the C. B. & Q. Ry. This house has a long double-deck platform in front with a loading track on either side. The upper deck is used for crushed ice and the lower deck for cake ice. In icing a train with crushed ice small carts are filled with crushed ice from the crusher and left in the crushing room until the train is about to pull in on the loading tracks. As soon as the train stops the covers are taken from the ice tanks in the cars and the crushed ice carts are wheeled alongside the platform opposite the tanks in the cars, and the crushed ice is transferred from the cart to the tank through an icing spout.

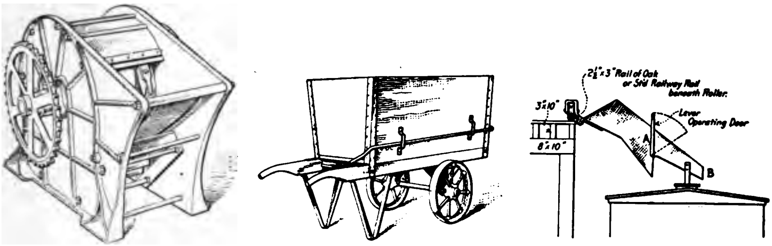
On the lower deck are the salt boxes, averaging about 50 ft. apart, and salt is thrown in on top of the crushed ice. In loading a train with cake ice the carts are not used, but the ice is skidded along the lower platform and into the tanks on the cars. In cases of very long platforms a mechanical conveyor is sometimes employed to carry the cakes along the platform.

In getting the ice out of the storage rooms to the crusher room and to the cake ice platform, elevators are employed in the division walls between the rooms and the ice is elevated by these to a runway in the cupola of the roof. At the Galesburg house this cupola contains an inclined skid, and the cakes slide down this by gravity to the center of the house, where they are delivered to the crusher or conveyed to the cake-ice platform. In some houses a mechanical conveyor is used to convey the ice from the top of the elevators to the center of the house above the crushing room. This is especially the case if the house is very long.

In Fig. 169 a crusher, cart and icing spout are shown. The crusher requires about 25 H.P. to crush 75 tons of ice an hour. A station of 20,000 or 30,000 tons storage capacity should be equipped with from 80 to 100 carts holding about 1000 lbs. each.

The spout shown in the figure is made for icing both sides of the car. The operator stands on the running board and by pulling down the lever raises the flap that covers the opening

A, and thus closes the opening toward *B*. This sends the ice out at *A*. By letting down the flap, he allows the ice to pass through and out at *B*. In the handling of the chute it is car-



A. Ice Crusher. *B*. Icing Cart. *C*. Icing Spout or Chute.

FIG. 169.—Apparatus Used at Icing Stations. (Mech. Mfg. Co.)

ried along by the operator on top of the car and when through with, it is pushed back on the platform out of the way.

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CHAPTER XV

SIGNALS AND INTERLOCKERS

109. Essentials of Signaling.

PRINCIPLES OF SIGNAL INDICATIONS RAILWAY SIGNAL ASSN. (1906)

(*a*) On all the high signals conferring or restricting rights a red light shall be the night indication for STOP. A yellow light shall be the night indication for CAUTION, and a green light the night indication for PROCEED.

NOTE.—The word caution to be used as indicating the function of a distant signal.

(*b*) The day indication of semaphore signals shall be given in the upper right-hand quadrant.

(*c*) The semaphore arm in the horizontal position shall indicate STOP, inclined upward forty-five (45) degrees, CAUTION, and inclined upward, ninety (90) degrees, PROCEED.

MEMORANDUM ON THE ESSENTIALS OF SIGNALING, INCORPORATED IN THE REPORT OF THE COMMITTEE ON TRANSPORTATION OF THE AMERICAN RAILWAY ASSOCIATION, MAY, 1911:

The reports of various Committees of the Railway Signal Association and the American Railway Engineering Association on the subject of signaling have been submitted to this Committee, with the request that the essentials of signaling be outlined or defined for the future guidance of the Committees.

The subject has been carefully analyzed and considered. There are three signals that are essential in operation and therefore fundamental, viz.:

1. Stop.
2. Proceed with caution.
3. Proceed.

The fundamental, "proceed with caution," may be used with the same aspect to govern any cautionary movement; for example, when:

(*a*) Next signal is "stop."
(*b*) Next signal is "proceed at low speed."
(*c*) Next signal is "proceed at medium speed."
(*d*) A train is in the block.
(*e*) There may be an obstruction ahead.

There are two additional indications which may be used where movements are to be made at a restricted speed, viz.:

4. Proceed at low speed.
5. Proceed at medium speed.

Where automatic block system rules are in effect, a special mark of some distinctive character should be applied at the stop signal.

The Committee therefore recommends:

Signal Fundamentals

1. Stop.
2. Proceed with caution.
3. Proceed.

Supplementary Indications to be Used Where Required.

4. Proceed at low speed.
5. Proceed at medium speed.

Stop signals operated under automatic block system rules should be designated by some distinctive mark to be determined by each road in accordance with local requirements.

SIGNAL PRACTICE AS DEFINED BY THE RAILWAY SIGNAL ASSN. (1913)

Recommendations of Committee I

Your Committee submits for approval the following two schemes of signaling in conformity with the recommendations of the Committee on Transportation.

Scheme No. 1.

Fundamentals.

1. Stop.................................... 

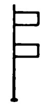
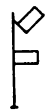
2. Proceed with caution..................... 

3. Proceed.................................. 

As a means of designating stop signals operated under automatic block-system rules, the following are suggested:

1. The use of number plate; or
2. The use of a red marker light below and to the left of the active light; or
3. The use of a pointed blade, the blades of other signals giving the stop indication having square ends; or
4. A combination of these distinguishing features.

Scheme No. 2.

	Fundamentals.	Supplementary Indications.
1. Stop..........................		
2. Proceed with caution..............		
3. Proceed..........................		
4. Proceed at low speed............................		
5. Proceed at medium speed....................		

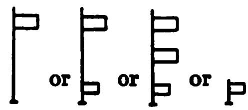
As a means of designating stop signals operated under automatic block-system rules, the following are suggested:

1. The use of a number plate; or
2. The use of a red marker light below and to the left of the active light; or
3. The use of a pointed blade, the blades of other signals giving the stop indication having square ends; or
4. A combination of these distinguishing features.

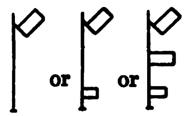
Having in view the practice of indicating diverging routes by several arms on the same mast, the Committee submits for approval the following to establish uniformity in this practice:

Scheme No. 3.

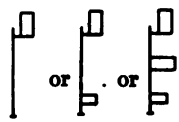
1. Stop. ....



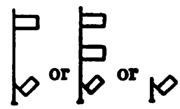
2. Proceed with caution. ....



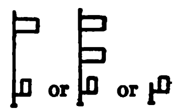
3. Proceed ....



4. Proceed with caution on low-speed route. ....



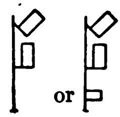
5. Proceed on low-speed route. ....



6. Proceed with caution on medium-speed route. ....

7. Proceed on medium-speed route. ....

8 Reduce to medium speed. . . . .



As a means of designating stop signals operated under automatic block-system rules, the following are suggested:

1. The use of a number plate; or

2. The use of a red marker light below and to the left of the active light; or

3. The use of a pointed blade, the blades of other signals giving the stop indication having square ends; or

4. A combination of these distinguishing features.

The above three schemes are submitted, after an earnest effort to carry out the Committee's instructions to submit a uniform scheme of signaling, with the idea that each scheme is complete in itself.

Block signals are generally made with pointed ends and interlocking signals with square ends (see Fig. 170) except the lower quadrant distant signal, which has a notched end. The home signals are generally painted red with a white stripe, although some roads prefer yellow with a black stripe. For night indications the use of green for clear appears to be superseding white, yellow is used for caution and red for stop in connection with the green for clear; but if a white light is used for the clear indication, then green is used for caution, the red in either case being the stop indication.

The first signals of fixed location for indicating a condition affecting the movement of trains were those where two roads crossed. These were of very crude form, consisting of a gate which could be swung across one of the tracks, leaving the other clear. Signals were next introduced to govern the movement of trains running on one track.

110. Train Order and Manual Block Signals.—The signals were at first for the purpose of indicating to the train crew whether or not orders had been received at the telegraph station for the train. The telegraph office was generally located at the

passenger station, and the train after receiving its orders, transmitted from the train despatcher through the telegraph operator, would run to the next station without further communication with the despatcher. Frequently the orders would be provided for meeting points between stations, in which case one of the trains would be required to take a siding at a designated place and time and wait for the other train to pass it before proceeding farther.

The track between the stations, where the despatcher can communicate with the train and control its movements, is called a block and the system of signaling is called a manual-block system to distinguish it from the automatic block system in which the signals are operated by electricity, actuated by a train or by certain conditions affecting the use of a block.

A modification of the manual block system is the controlled-manual block. This is a block system in which the signals are operated manually, but so constructed as to require the co-operation of the signal men at both ends of the block to display a clear or a caution block signal.

The signals used in the manual block system are shown in Figs. 170*D* and 171. A great many of these signals are being mounted on iron poles and are upper quadrant.

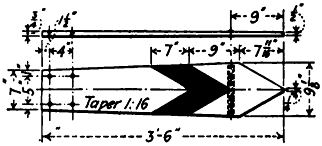
Frequently small interlocking plants of four or eight levers are employed to interlock the switches at the station, which are thrown from the tower by the signal man.

With an increase in the density of traffic, telegraph offices are located between the stations and sidings provided for the trains at these points so that the blocks are shortened. When, however, the conditions of the road require blocks at frequent intervals the cost of operating the manual block, on account of the large number of signal men employed, becomes so great that the automatic block system can be used.

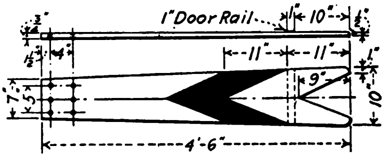
111. Automatic Block, General.—In laying out the block signals on a piece of track it is necessary to place the signals with reference to the grades, curves and speeds trains run over different parts of the line. On descending grades the blocks should be made longer than on ascending grades, as the speed is

greater and a greater distance is required in which to stop a train. In general the minimum length of block is the distance in which a train can be stopped on that particular part of the line.

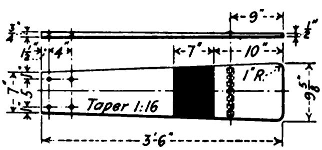
Obviously, the shorter the block the greater the train capacity of the road, as the trains with short blocks would be closer together than in the case of long blocks. The minimum length



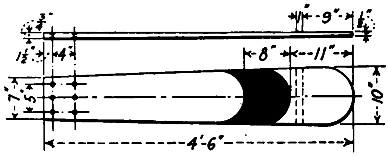
A. Upper Quadrant Automatic Block Signal Blade.



C. Lower Quadrant Distant Signal Blade.



B. Upper Quadrant Interlocking Signal Blade.



D. Lower Quadrant Train Order Signal Blade.

FIG. 170.—Signal Blades.

Note.—Sigs. *A*, *B*, and *D* red with white stripe; Sig. *C* yellow with black stripe.

of block is seldom used, and the lengths ordinarily employed vary from 4000 ft. to 12,000 ft., depending upon the density of traffic to be handled.

The development of the present upper quadrant signal-block system can be understood from Figs. 172, 173 and 174. Fig. 172 shows a block system with home signals at the entrance of each block and distant signals which give an advance indication of the position of the home signals. *ab* is the length of the block, signals a_1 and b_1 are distant signals which show the engineer of the train what to expect at the next home signal. He may pass

the distant signal, but if this is in the caution position he must put his train under control and be prepared to stop at the home

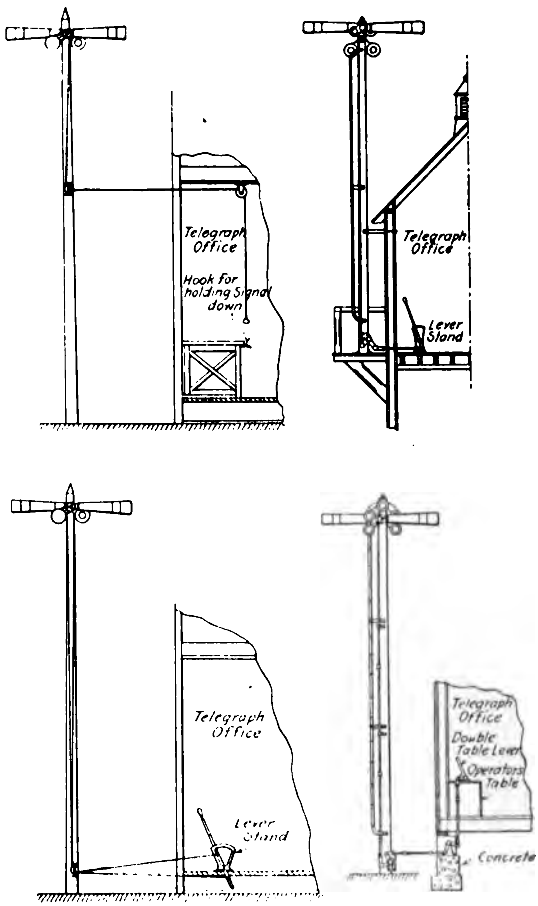


FIG. 171.—Train Order and Manua lBlock Signals. (Federal Signal Co.)

signal if it is at danger. This arrangement is used only on light traffic roads when the length of the block is long.

On roads with shorter blocks the signals may be arranged as shown in Fig. 173, with the home and distant signals mounted on the same posts. It is developed by shortening the length of the blocks until a_1 and b come so close together that they may be mounted on the same post.

Fig. 174 illustrates the arrangement and use of three-position signals operating in the upper quadrant. These are rapidly superseding the two-position signals shown in Figs. 172 and 173. Each signal is a home signal and distant signal combined. *a* is a home signal in the "stop" position; the arm is horizontal and

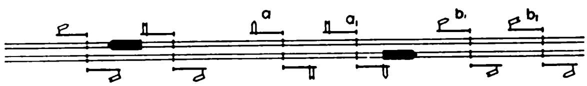


FIG. 172.—Block Signals on Separate Posts.

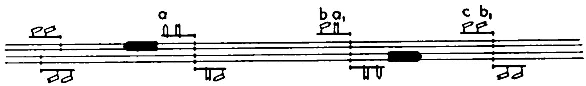


FIG. 173.—Block Signals with Home and Distant Signals on Same Post.

FIG. 174.—Three-position Block Signals.

the meaning is the same as *a* in Fig. 173. *b* is a home signal in the "caution" position, and *c* is a home signal in the proceed position.

The semaphore is primarily a position signal, yet in Figs. 172 and 173, both arms *a* and a_1 are in the horizontal position, but have two entirely different meanings. The signals shown in Fig. 174 are therefore theoretically more correct in this respect.

112. Automatic Block. Track Circuit.—The track circuit is the foundation of every automatic block system. It was invented in 1872 and has been used in all kinds of signaling and protective schemes. The installation of a section of track circuit is very simple and merely consists in removing one of the

metal joints from each rail at each end of the section and replacing them with insulated joints; the bonding together of the intermediate rails by running bonds of No. 8 galvanized iron wire around each joint and connecting a battery across the rails at one end, and an electromagnet across the rails at the other end.

Fig. 175*A* shows a pair of rails connected at one end to an electric battery and at the other to a relay. When the current is allowed to flow freely through the rails and through the relay the armature of the relay acting as a switch causes a secondary electric circuit to be closed. The signal is on this secondary circuit and the flow of current which takes place through the operating mechanism of the signal keeps it in the "clear" position shown at *c* of Fig. 174.

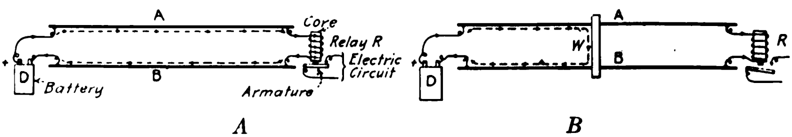


FIG. 175.—Track Circuits.

In Fig. 175*B*, however, let us imagine that a train is passing over the track, the current from the battery now flows through the wheels and axles of the train and returns to the battery and does not flow through the relay, with the result that the latter is demagnetized, allowing the armature to drop and thus opening the secondary circuit and causing the signal to go to danger. It will be noted that the same effect is produced if one of the rails is broken or a switch left open, as the electric track circuit is thus interrupted.

A signal may also be controlled by another signal in advance by means of line wires in such a way that its semaphore cannot move to the vertical position, indicating proceed, until the signal in advance has moved to or beyond the inclined or 45 degrees "caution" position. Thus one signal can give advance information to an approaching train of the position of the next signal. Such a condition is shown by *b* in Fig. 174.

113. Automatic Block Signals.—The first electric signals were of the enclosed disc type. On account of the disc being enclosed very little power was required to operate the signal, but its indications were hard to read, especially during snow storms, as the snow would accumulate on the face of the signal, making it difficult to see the disc.

The first clockwork disc signals were followed by automatic semaphore signals operated by compressed air or gas, controlled by electric power. The expense incident to the installation of this type of signal was very great, and in 1897 Mr. J. W. Lattig designed an electric semaphore signal which, considering the period of its inception proved quite successful.

Fig. 176 shows the model 2*A* signal of the General Electric Co. Fig. *A* illustrates the top of mast mechanism. In this arrangement the motor shaft is directly connected to the semaphore shaft, and on account of its greater mechanical efficiency is preferred by many signal engineers to the base of mast arrangement shown in Fig. *B*. Fig. 177 shows a block signal.

In A. C. (alternating current) block systems the signals are operated with energy supplied from a transmission line of about 2200 volts, and a transformer at each signal reduces this voltage to 110–120 volts for the signals and about 4 to 12 volts for the track circuit.

In the D. C. (direct current) system the signals using current at about 10 volts are operated by either primary batteries or storage batteries. The storage batteries are either charged from a transmission line or are in portable sets so that they may be taken to a central station to be charged.

The current for the track circuits at from 1 to 3 volts is generally furnished by gravity batteries located in battery chutes alongside the track. These chutes are separate from the battery wells which contain the batteries to operate the signals.

While most of the automatic block signaling in this country is D. C., the use of A. C. current in recent years has been employed on considerable mileage. Wherever the track rails conduct current for other purposes, such as propelling of trains, it is necessary to use A. C. current for the track circuit.

A. Top of Mast Mechanism. *B*. Bottom of Mast Mechanism.

Fig. 176.—Model 2A Signal, General Railway Signal Co.

On steam roads the advantage of this sytem is the additional power available to operate the signals and light them, and its disadvantage the additional cost of the transmission line.

In block signal territory each switch is insulated so that the track circuit passes through it unbroken. A circuit controller is attached to the point of the switch and adjusted so that if the switch is open one-fourth of an inch the track circuit will be short-circuited as if by the presence of a train. For the

Fig. 177.—Block Signal.

guidance of trains coming out of a siding onto the signaled track, a switch indicator (Fig. 178) mounted on an iron post near the switch is employed. The switch indicator is usually so controlled that when a train is approaching on the main track two blocks away the miniature semaphore is set to the "stop" position to warn the train in the siding not to open the switch. All sidings are made a part of the track circuit up to the fouling point to protect trains on the main track from cars which may not clear it.

114. Mechanical Interlockers.—Fig. 179 shows a typical plan of a grade crossing protected by a mechanical interlocking plant. This consists essentially of an interlocking machine, located in the tower, composed of a number of levers which operate the various derail and signal functions. These levers are interlocked so that only the derails and signals for one of the routes may be set at one time. The numbers on the plan correspond to the numbers given the levers and a manipulation chart is placed in the tower for the convenience of the operator in setting up the routes.

FIG. 178.
Switch Indicator.
(Federal Signal Co.)

When a movement is desired over any one of the tracks the derails for the route are set for the passage of the train, the home signal is then cleared, and finally the distant signal is cleared which locks the movements of the functions on the other track in positions to prevent the trains on that track using the crossing.

Fig. 180 shows the Saxby and Farmer machine.

On many roads the distant signals are electrically connected, and when this is done the apparatus for operating the wire-connected signals is omitted from the machine. A rocker shaft is quite generally employed as shown in Fig. 181, instead of the crank illustrated in Fig. 180.

Before the lever can be moved from its normal position, the latch must be raised. This operates the bars in the locking; dogs are riveted to these bars which, through the medium of cross locks, lock the bars on the levers controlling functions conflicting with those operated by the lever it is desired to throw. Consequently the latch cannot be raised nor the lever moved unless the conflicting functions are in their proper positions, and after the latch is raised these conflicting functions are locked.

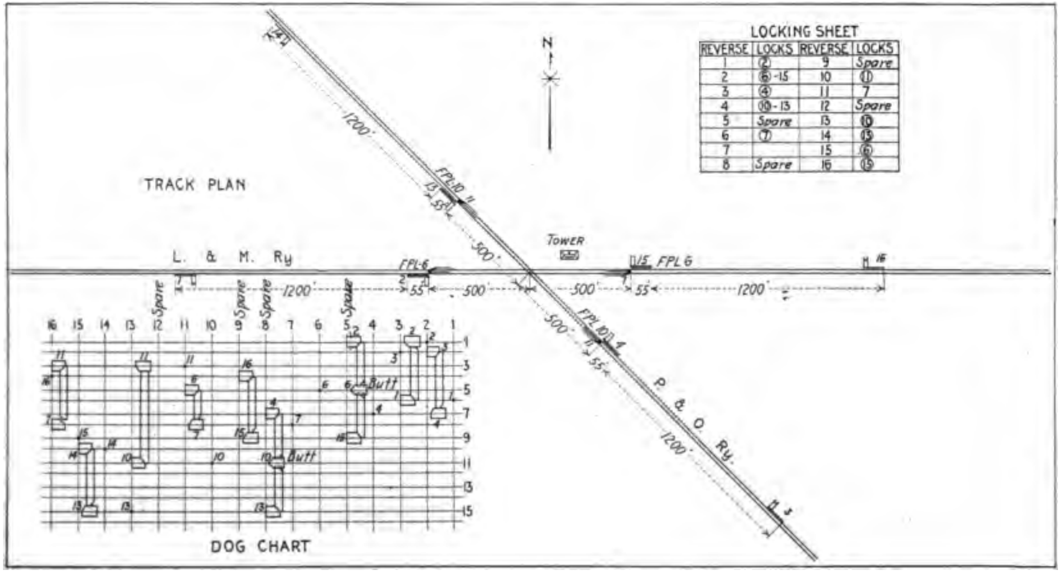


FIG. 179.—Railroad Crossing Protected by Mechanical Interlocking Plant.

When the lever is thrown the latch is dropped, and this releases those levers which are to be thrown next.

The dog chart, Fig. 179, is the working drawing by which the locking is laid out and is a diagram of the locking as it appears in the machine. The locking sheet is prepared before the

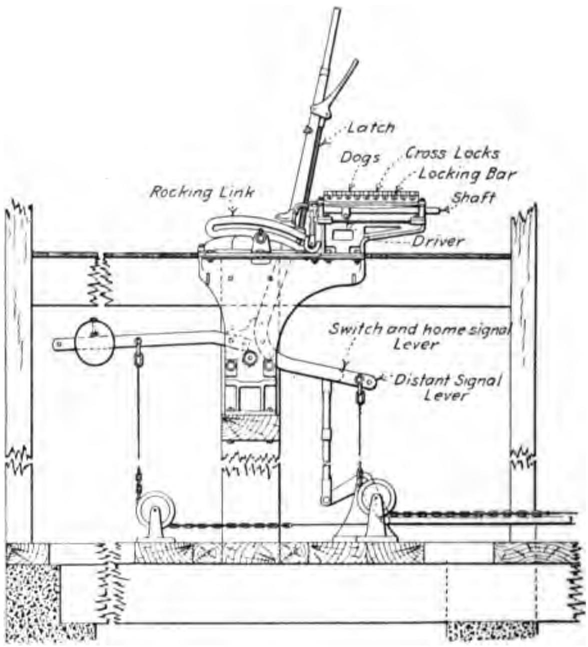


FIG. 180.—Saxby and Farmer's Interlocking Machine.

dog chart is made and shows the locking required for each lever.

The normal position of the lever and function it controls is the danger position. The reverse position is the clear or proceed position. In the locking sheet in the column headed "locks" the numbers in circles refer to the reversed position,

and the numbers without circles refer to the normal position of the lever corresponding to the number.

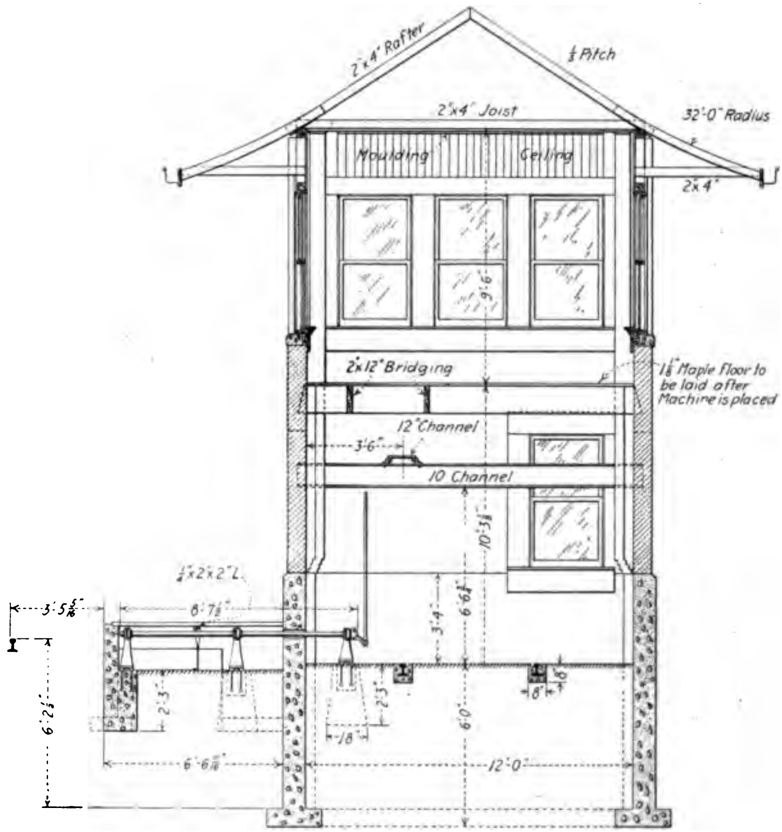


FIG. 181.—Interlocking Tower.

In reading the locking sheet we see on referring to the track plan that the distant signal No. 1 locks the home signal No. 2 reversed. No. 2 reversed locks the facing point locks 6 reversed

and the opposing signal No. 15 normal. No. 6 reversed locks the derails No. 7 reversed.

Therefore, by reversing lever No. 1, which clears distant signal No. 1, all the functions on the route are locked in the reverse position and a clear route through the interlocking is assured for the passage of the train given a clear indication by the distant signal No. 1, and the signals are set against trains approaching the crossing on this track in an opposite direction.

This is, however, not enough to give the train a safe passage over the crossing, and it must be protected from trains which may approach the crossing on the other track. Bearing in mind that derails No. 7 are now locked reversed, it will be seen from the locking sheet that derails No. 11 are locked normal and trains cannot get to the crossing from the track on which these derails are situated.

It will be observed that the two derails No. 7 and their facing-point locks No. 6 are operated by one lever, as they must always be in the same position. This is also true of Nos. 10 and 11.

Referring again to the dog chart, the numbers at the top of the chart are the levers and those at the side the locking bars, which are numbered in the order in which they are placed in the machine, commencing with No. 1, next to the levers. The small circles at the intersections of the vertical lines and the horizontal lines show the lever by which the bar is worked, for example, the latch on lever No. 1 moves bar 6.

To understand thoroughly the locking, let us assume that a train is approaching the crossing from the west on the L. & M. Ry. The first signal to be passed by the train is the distant signal No. 1. By referring to the dog chart it will be seen that the dog on bar 6, operated by the latch on lever No. 1 will prevent the latch being raised (and the bar moved) until lever No. 2 is reversed. The dog to the left on bar 1 will prevent lever No. 2 being reversed until lever No. 6 is reversed, and the dog to the left on bar 5 will likewise prevent this lever being reversed until the dog to the right on bar 8 is moved. This bar is moved by the latch on lever No. 7, and it will be seen

that reversing this lever locks lever No. 11 normal by means of the dog to the left on bar 8.

The towerman in setting up the route for the train must therefore close the derails No. 7, lock them with locks No. 6, clear the home signal No. 2 and finally clear the distant signal No. 1. The approaching train can then pass through the interlocking with a clear route and protected from trains on the other track.

It will be noticed on the dog chart that the locking of No. 15 normal by reversing No. 2 is accomplished by means of a " butt." This arrangement is employed to avoid the duplication of locking, as with the locking, as shown, lever No. 2 reversed locks lever No. 6 reversed and lever No. 15 normal with one dog.

The levers are connected to the derails and switches by pipe lines running alongside the track. The home signals are also generally pipe-connected, but the distant signals, where not electrically operated, are wire-connected. The use of electric distant signals, as shown in Fig. 182, permits these to be placed farther away from the home signals than is possible in the case of wire-connected signals.

The pipes are supported by roller carriers on wood, iron or concrete foundations, and when over 50 ft. long a compensator, to take care of expansion and contraction, is used. Wire lines are carried in the same manner, but the expansion and contraction is provided for by adjusting screws.

All switches within the limits of the interlocking should be controlled from the tower, so that no unauthorized movement may be made.

Fig. 182 shows a more complicated crossing that that given in Fig. 179.

In Fig. 182, Nos. 1, 2 and 32 are switches. Switches were formerly quite generally operated by a mechanism known as a switch and lock movement, as shown in Fig. 183. It will be seen that the first part of the movement of the lever in the tower unlocks the switch; the jaws in the mechanism then throw the switch and the last part of the stroke locks the switch.

The use of a switch-and-lock movement is not considered good practice on main lines (in mechanical interlocking), and

its use is now confined largely to side tracks. For the main line a facing-point lock is employed. This is shown in Fig. 184 and requires two levers—one to throw the switch and another to operate the lock. The term facing-point lock is used because in the early days only facing-point switches, or those with the switch point facing the direction of traffic, were locked in this manner.

Connected to the lock is the detector bar. This is a bar which lies against the edge of the rail and is so arranged that when the lock is operated the bar is first moved, rising slightly

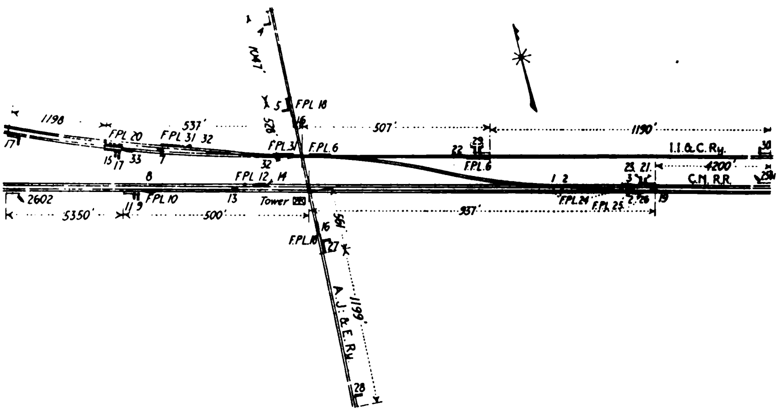


FIG. 182—Railroad Crossing with Electric and Mechanical Signals.

above the top of the rail. If a train is passing over the switch the bar cannot be moved, which prevents the leverman from throwing the switch under a train; the bar is made long enough (usually 55 ft.) to engage the wheels on both trucks of a car.

It will be observed that no detector bars are shown for the switches and derails on the double track line in Fig. 182. Here a detector circuit takes the place of the detector bar, the circuit being extended to provide route locking. That is after a train passes either distant signal 2581 or distant signal 2602 the levers in the tower are electrically locked, so the tower man cannot open the switches or derails on the track upon which the train is approaching.

Derails are used at the signals controlling the crossings for the purpose of derailing a train if the signal should be disregarded. In Fig. 182, Nos. 3, 8, 14, 16, 22, 26 and 32 are derails. Derails are of two general kinds, first, where the track is broken,

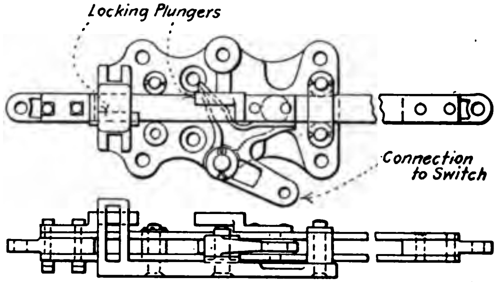


FIG. 183.—Switch and Lock Movement, Model 2, Union Switch and Signal Co.

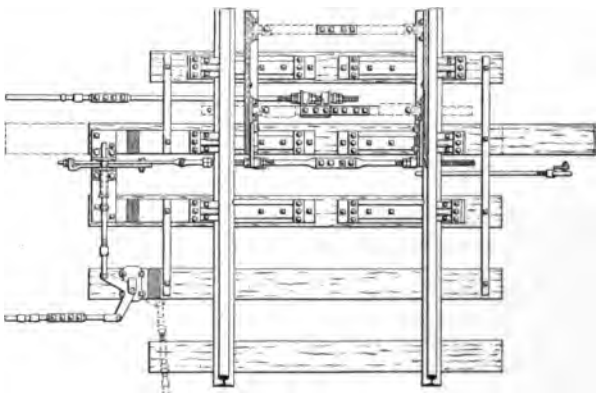


FIG. 184.—Facing Point Lock. (Ry. Sig. Assn.)

as in the case of the point derail, which is an ordinary switch point; and second, where the track is unbroken, as with the Wharton or Hayes derails described in Chapter VII.

All of the derails shown in Fig. 182 are Wharton, or lifting derails, except No. 32, which is a Hayes derail located on a side track.

In Fig. 182 the high signals with square-end blades are home signals, and in lower quadrant signaling the end of the blade is notched for the distant signals. Signals Nos. 4, 17, 28 and 30 are distant signals. Nos. 2581 and 2602 are also distant signals, but these are part of the automatic block system operating in the upper quadrant and electrically connected with the home signals. The relation between distant and home signals is the same in interlocking as that described in the operation of the block system, the function of the distant signal being to give an advance indication of the position of the home signal.

The distant signals Nos. 4, 28 and 30 are mechanically connected signals operating in the lower quadrant, and the distant signal No. 17 is a lower-quadrant signal also, but electrically operated. The home signals Nos. 5, 27 and 29 are mechanical lower-quadrant signals. No. 17 is an electrical lower-quadrant signal and Nos. 9 and 23 are electrical upper-quadrant three-position signals which also act as block signals.* The dwarf signal No. 13 is electrically operated and governs the back-up movement against traffic. Signal No. 11 is an electrically operated two-position upper-quadrant signal to let trains down to the crossing at very slow speed. It is sometimes called a call-on arm.

The last report of the Interstate Commerce Commission shows the use of interlocking as follows:

Types of Plants.	Number of Plants	Per Cent	Number Of Working Levers
Mechanical..........	4850	80	—
Electric..............	729	12	—
Electro-mechanical....	262	4	—
Electro-pneumatic....	241	4	—
Pneumatic...........	32	—	—
Total.........	6114	100	144,506

* Some roads, notably the Pennsylvania, do not consider these home signals as acting in place of the block signal, but provide an additional home signal at the leaving limits of the interlocking to govern the movement of trains entering the block ahead.

115. Power Interlockers. Electro-Pneumatic.—The electro-pneumatic system derives its name from the fact that compressed air is employed to operate the switches and signals, and electricity is used to control the admission and discharge of air to and from the cylinders operating the functions.

The system consists of the following elements:

First.—A source of compressed air supply at approximately 75 lbs. per square inch.

Second.—A source of current supply at approximately 12 volts.

Third.—An interlocking machine for controlling the operation of switches and signals.

Fourth.—Switch-operating mechanisms with their controlling and indicating circuits.

Fifth.—Signal-operating mechanisms with their controlling and indicating circuits.

The compressed-air supply consists generally of two compressors, one as a relay to the other, which may be driven by electric, steam or other available power.

Frequently, especially at terminals, a source of compressed-air supply exists, for other purposes, such as cleaning of cars, operation of tools, etc. This supply may be used with little additional expense, as the interlocking system requires a comparatively small amount of air.

At interlocking sites where no supply of compressed air exists, there is usually available a source of direct or alternating current which may be utilized for the operation of air compressors. In such cases an automatic governor is provided as part of the compressor equipment, which is so regulated that when the pressure in the main air pipe reaches the maximum desired the compressor is automatically stopped, and when the air pressure reaches the minimum desired the compressor is automatically started.

The work performed by electricity in the control of the electro-pneumatic system is small and both the pressure and volume of the current used are low. All of the actual work is performed by compressed air, the function of the electricity being simply the control of the various air valves by electro-magnets, and the

control and operation of the electric locks, relays, indicators and similar appliances.

The electro-pneumatic interlocking machine (Fig. 185) consists of small levers conveniently arranged in a common frame and adapted to the operation of mechanical locking similar in character to that employed in mechanical interlocking machines, but of smaller design. Each lever in the machine also operates

FIG. 185.—Electro-Pneumatic Interlocking Machine. D. L. & W. R. R. Hoboken Terminal. (Union Switch and Signal Co.)

a number of electric contacts, and attached to each lever are one or more electric locks.

The mechanical locking is provided for preventing the operation of levers which, if moved, would conflict in function with one or more levers.

The contacts control electric currents by which switches and signals are operated by the levers, and are also used for opening and closing different circuits as required by the many combinations of lever positions.

The electric locks are provided for restraining lever operation according to conditions remote from the machine when these are adverse to their safe operation, such as preventing final movement of levers until the operated unit has responded to the initial lever movement and preventing the initial movement of

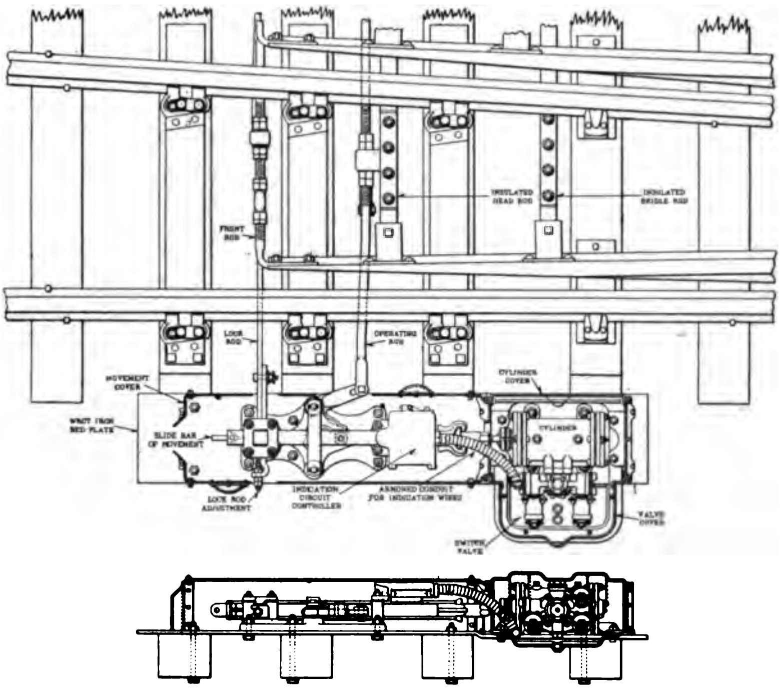


FIG. 186.—Electric-Pneumatic Switch and Lock Movement. (Union Switch and Signal Co.)

switch levers by train action where detector track circuits are used in place of mechanical detector bars.

Each set of switch and frog points embraced in the track system is operated by a switch and lock movement (Fig. 186). The switch and lock movement is operated by direct action

of the piston of a double-acting cylinder, of which the admission and exhaust are controlled by a slide-valve usually mounted upon the cylinder. The operation of the slide-valve is effected by three electro-magnets, mounted on the valve, which are connected to the lever contacts of the machine by three individual wires.

Each signal of the system is operated by a single-acting cylinder, the admission of air to which is under the control of a pin valve and electro-magnet.

The power interlocking plants require much less space than the mechanical machine, and as the small operating levers entail very little effort on the part of the leverman to manipulate them, and as less levers are required than in a mechanical plant, fewer levermen are necessary for the operation of large plants.

The electro-pneumatic interlocking plant at the St. Louis Terminal Railroad Association of St. Louis illustrates this. The machine for operating this plant, which includes 44 double-slip switches with movable-point frogs, 65 single switches and 194 signals, is about 44 ft. in length over all, and contains only 215 levers, of which 33 are not in use, being available for future additions to the plant. A mechanical plant to operate this terminal would have contained 528 levers, and been 245 ft. long. Five levermen on the busiest shift operate the electro-pneumatic machine, while not less than twenty men would have been required for a mechanical machine under similar conditions.

The interlocking at the Union Station at Washington and at the Pennsylvania Terminal at New York is of the electro-pneumatic system. At the former, three plants are used; the total number of lever spaces in the three frames is 291, of which 240 are active levers leaving 51 spaces for future use. The largest machine, that at K Street, has a 191-lever frame with 162 working levers.

At the Pennsylvania Terminal the system of interlocking comprises 11 interlocking machines, varying in size from 11 lever to 179 lever frames, having a total of 516 working levers, of which 40 are used for traffic and special locks and 476 to control 92 double-slip ends, 46 pairs of movable-point frogs, 267 single

switches, 451 two- and three-position high signals and 187 two- and three-position dwarf signals.

116. Power Interlockers, Electric.—An installation of an electric interlocking system comprises the following principal elements:

First.—A source of power consisting of a storage battery with its charging unit.

Second.—Power control apparatus introduced between the source of power and the interlocking machine.

Third.—An interlocking machine with levers for the control of the switch and signal mechanisms.

Fourth.—Switch mechanisms, their operating and indicating circuits.

Fifth.—Signal mechanisms, their operating and indicating circuits.

Sixth.—Means for the prevention of unauthorized movement of any function.

The source of power from which the system is operated consists of a storage battery having an approximate working potential of 110 volts. The battery is charged by a power-generating unit, which may be a generator driven by a small gasoline engine or a motor generator set when the current is taken from an outside source.

In explaining the apparatus used in electric interlocking, the General Railway Co.'s machine will be used as being typical of most electric interlocking. The essential differences in this interlocking as compared with other makes lie in the dynamic indication given by all principal switch and signal functions, without which indication the next sequence of operations cannot be carried out (some systems use a battery indication in place of the dynamic), and the means for prevention of unauthorized function movements. The cross-protection system prevents the unauthorized movement of any function due to energy improperly applied to its circuit through a cross between wires, by cutting off current from the function in the event of such an occurrence.

Fig. 187 illustrates a front view of an electric interlocking machine and in Fig. 188 is shown a cross-section of the machine.

All the movements of switch and signal functions are controlled by the levers.

In explaining the operation of the lever, its movement is considered as being divided into three parts, the preliminary, intermediate and final. It should be observed that the preliminary and intermediate part usually constitute one continuous movement, it being necessary to separate them, however, when considering the detail operation of the lever.

FIG. 187.—Electric Interlocking Machine, Model 2, Unit Lever Type, General Railway Signal Co.

The following description is based on the operation of the switch lever. Each of these levers is provided with a cam slot, by means of which intermittent motion is transmitted to its respective tappet bar and thence to the cross-locking. In Fig. 189*A* the dotted circles 1 to 5 in the cam slot indicate the positions of the locking-tappet[1] roller which correspond with the like numbered positions of contact block *Z*. In the preliminary

movement of the lever from position 1 to 2, the locking tappet is moved through one-half of its stroke, this movement locking all levers which conflict with the new position of the lever in question; in this movement no change whatever is made in the operating circuits. During the intermediate part of the travel from positions 2 to 4, the tappet bar remains stationary and

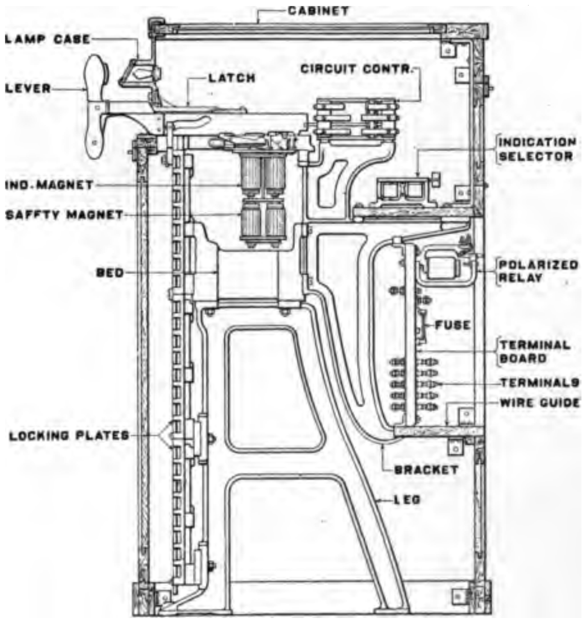


Fig. 188.—Cross-section, Electric Interlocking Machine, Model 2, unit Lever Type, General Railway Signal Co.

the contact block Z is moved out of engagement with springs YY and into contact with springs XX, as shown in Fig. 189B, this setting up the circuits for the operation of the function. The lever is held at this point (position 4), through the mechanical design of the lever proper, until such time as the function having moved to a corresponding position, generates a dynamic

indication current which effects the release of the lever and permits its movement to position 5. During this final movement from position 4 to 5, the stroke of the locking tappet is completed, thereby unlocking all levers which do not conflict with the new position of the operated lever.

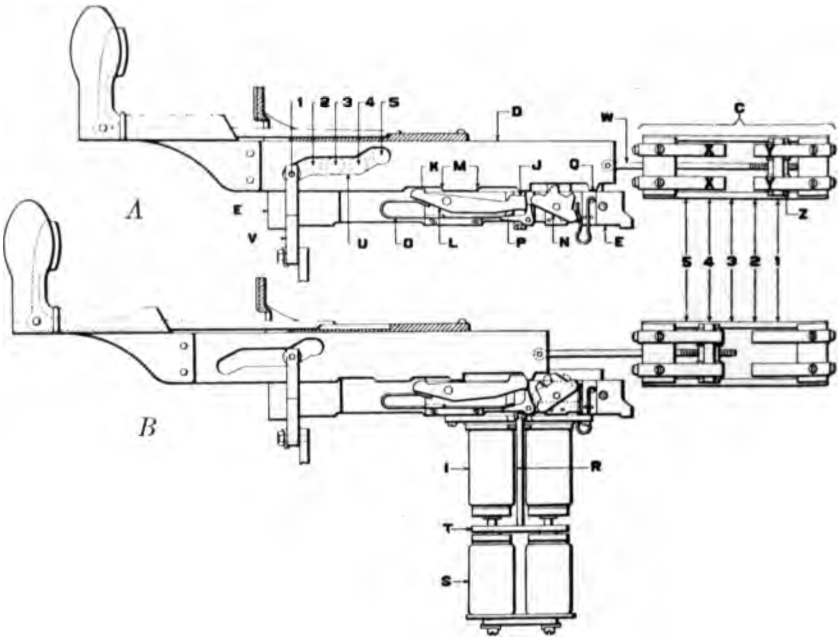


FIG. 189.—Switch Lever, Electric Interlocking Machine Unit Type, General Railway Signal Co.

The method by which the lever is prevented from completing its stroke, until the controlled function has moved to a corresponding position and has sent in its indication, is illustrated by the following: in moving from positions 1 to 2 projection *M* on the lever coming against projection *K* on latch *L*, causes, the latch to assume the position shown in Fig. 189*B*. This brings projection *J* on latch *L* into the path of tooth *Q* on the lever.

In moving from position 2 to 4, tooth Q engages with cam N, rotating it to the position shown in Fig. 189B. As it passes the central position (shown dotted in Fig. 189B) it comes in contact with dog P, which is forced under latch L, thereby locking the latch L in the position assumed. The lever is stopped at position 4 by tooth Q coming against projection J on latch L as previously explained. The indication current, by flowing through magnet I, lifts armature T, which causes plunger R to strike dog P and trip it out from under latch L. The latch L then drops to the position shown in Fig. 189A, thereby releasing the lever and permitting its final movement to be accomplished.

The movement of the lever from reverse to normal is performed in a manner similar to that described above. Once the lever has been moved to, or beyond, position 3, it can neither be moved forward beyond position 4 nor back beyond position 2 without the receipt of an indication.

The movement of the signal lever is identical with that of the switch lever except that no electrical indication is required during the reverse movement, the lever not being checked at position 4 due to a change in the design of dog P, which is mechanically tripped at this point from under latch L by cam N. The mechanical locking insures that before a signal can be given for any route, all switch and derail functions in the route are thrown to the proper positions and locked in that position, and all opposing signals are in the stop position. No changes can be made in the position of any of these functions until the lever controlling the signal displayed at proceed has been replaced to its full normal danger position.

The locking plates are securely attached to the front of the machine frame, as shown in Fig. 187, the number depending upon the amount of locking required at each individual plant.

The locking plates are designed with vertical and horizontal slots, the locking tappets, one of which is attached to each lever, being fitted in the vertical slot directly beneath its respective lever. Movement is transmitted from the lever through the medium of the tappets to the cross-locking, which slides back and forth in the horizontal slots of the locking plates.

To facilitate the manipulation of the levers of the interlocking machine, it is customary to mount within full view of the leverman a diagram of the track layout, showing the relative location of all interlocked switch and signal functions, also a chart listing the various routes through the plant and the order in which the levers are to be moved in setting up each of these routes. By referring to the chart, the leverman is guided in manipulating the levers in the sequence imposed by the mechanical locking between levers, thus aiding him greatly in the handling of the traffic passing through the plant.

The track diagram and manipulation chart are usually combined in one plan, as shown in Fig. 190, and mounted in a single frame, unless their combined size is prohibitively large, in which case they are framed separately.

For a long time it has been customary to give to the leverman an indication of the trains approaching the interlocking plant; with the advent of the route locking and the semi-automatic control of signals, and the consequent general use of track circuits within the interlocking limits, this practice has been extended to indicating at the interlocking station the condition of all the track sections within the plant. This supplements the information given by the track diagram and manipulation chart, and adds considerably to the facility with which the traffic is handled.

The approach sections are usually repeated by disc indicators and the different track sections between the home signal limits by semaphore indicators. These are generally located on the wall of the operating room near the track diagram, being mounted either separately with individual covers or on a common frame with a single cover.

A method of indicating the occupancy or non-occupancy of the various track sections, rather more elaborate than by the use of repeating indicators, is through the employment of the illuminated track diagram. This type of indicator is of great assistance on extremely busy plants where it is necessary to know when a train has cleared each route or section of a route, in order promptly to prepare for the next train movement. It is prac-

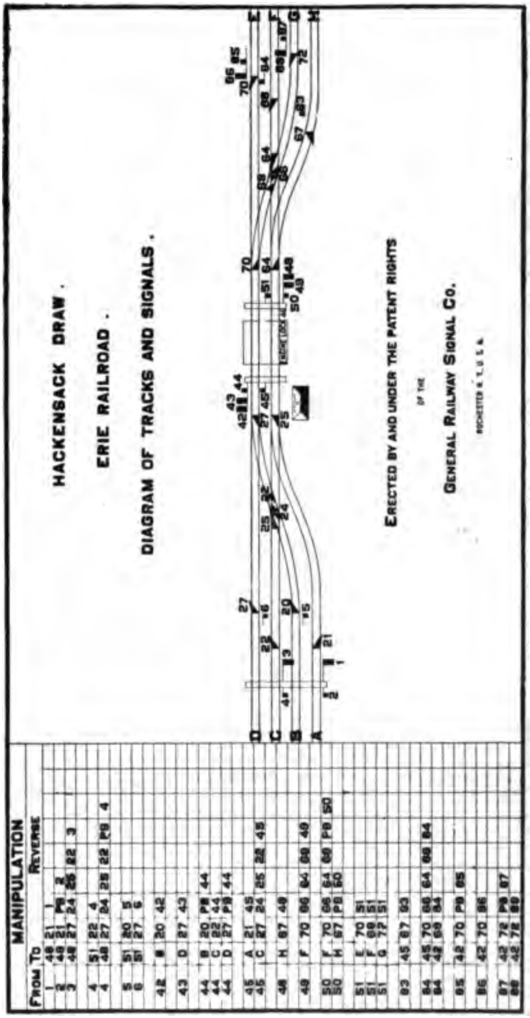


FIG. 190.—Track Diagram and Manipulation Chart.

tically essential wherever it is not possible for the operator to obtain a clear view of the tracks within the interlocking limits.

The device consists of a boxlike frame, the front or cover of which is glass, painted to leave transparent the track layout and to show the relative location of the various switch and signal functions. One or more miniature incandescent lights are located in a slot or channel behind each track section, the condition of the track circuit usually being indicated by whether or not the bulbs are lighted.

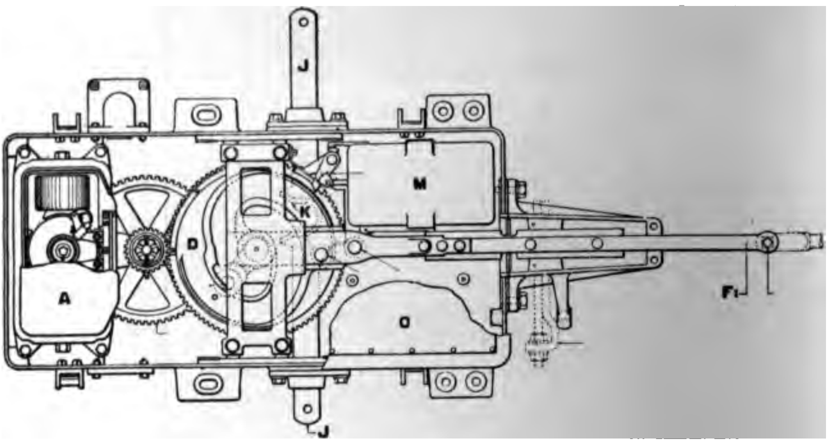


FIG. 191.—Model 4, Switch Machine, General Railway Signal Co.

The switch and derail functions are operated by switch and lock movements driven by series-wound D.C. motors.

The Model 4 switch machine of the General Railway Signal Co., shown in Figs. 191 and 192, is designed with all operating parts within one case. The case, which affords protection against the weather, provides a base plate for the mechanism, being bolted through the tie plate to the head block and the next tie back. The operating parts consist of the motor *A*, a train of spur gears, the main or cam gear *D*, the pole changer *M*, the throw rod *J* and locking bar *F*.

The motor through the medium of the train of gears drives

FIG. 192.—Switch Machine, Chicago Terminal, C. & N. W. Ry.; Model 4, General Railway Signal Co.

FIG. 193.—Dwarf Signal, Electric Division, New York Central; Model 2A, General Railway Signal Co.

the cam gear, from which gear the various parts of the s machine are operated.

The intermittent movement of the locking bar and de bar is accomplished by the engagement of rollers on the lo bar with the cam slot on the upper side of the main gear. gered locking is provided by the arrangement of the do

FIG. 194.—Lake Street Interlocking Plant, Chicago Terminal, C. &] Ry. (General Railway Signal Co.)

the locking bar, these dogs being placed so that after one do been withdrawn to release the lock rod, the switch points mu moved to the opposite position before the other dog can ent slot in the lock rod. The throw rod is locked in both extreme tions of the switch by a bolt operated from the cam movem

The switch points are thrown at the proper time by a roll the lower side of the main gear engaging a jaw in the throw

The signal mechanisms are of two types:

First, the non-automatic, which is entirely under the control of a lever in the interlocking machine. Generally speaking, this type is furnished for dwarf signals and for such high signals as will at no time require track-circuit control.

Second, the semi-automatic, which is operated under the joint control of a lever in the interlocking machine and the track circuits in such sections of track as are governed by the signal arm.

Fig. 193 shows a dwarf signal. The mechanism, which is the same for dwarf and high signals, consists essentially of three main parts, the motor, a train of gears and the circuit breaker. These are all housed in a weather-proof case, which is provided with doors to give convenient access to all parts.

When used for the operation of high signals, it is fastened to a clamp bearing (Fig. 176*A*) which carries the semaphore shaft, the design of this bearing permitting the mechanism to be supported at any desired height on the signal mast and at any angle to the track. Fig. 194 presents a view of the Lake Street interlocking plant at the Chicago Terminal of the Chicago and Northwestern Ry.

The installation of electric interlocking at this terminal is as follows:

Lake St.	Plant	212 lever spaces
Clinton St.	"	168 " "
Noble St.	"	80 " "
Division St.	"	120 " "
Carpenters	"	64 " "
Total, 5 plants		644 " "

At the Grand Central Terminal of the New York Central Ry., New York:

Plant "A"	360 lever spaces
" "B"	400 " "
" "C"	160 " "
" "F"	80 " "
" "U"	144 " "
Total, 5 plants	1144 " "

Plant " B " is the largest power plant in the world.

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